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Implementation of Blended Learning for a Large Size Engineering Mechanics Course

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ABSTRACT

Engineering mechanics is a core course for mechanical engineering university students. In recent years, the lecturers of a second-year undergraduate engineering mechanics course faced many new challenges arising from ever-increasing class sizes, as well as evolving learning styles and expectations of new generation students due to advances in technology. This paper describes the evolution of a mechanics course in the School of Mechanical and Manufacturing Engineering at the University of New South Wales using blended learning. Significant changes were implemented to (a) reduce the administrative burden associated with the large number of students, (b) maintain student interest and engagement throughout the semester, and (c) successfully deliver the learning outcomes. Student participation was observed to increase with integration of additional information and communication technology, as well as implementation of online assessments into the course structure. Surprisingly, implementation of the blended learning did not improve student academic performance in the summative assessments. This paper reflects what we have learned in the development of this blended learning mechanics course.

Key words: Blended learning; Course design; Course assessment

INTRODUCTION

Over the past decade, there has been a significant increase in student enrolment at many universities and colleges in OECD (Organisation for Economic Cooperation and Development) countries (Mulryan-Kyne, 2010). A range of issues with large class sizes that are frequently encountered by teaching staff have been reported in the literature. A large sized class makes it more difficult for teaching staff to elicit student engagement and to monitor students' understanding of the course content (Gibbs, 1992; Gibbs & Jenkins, 1992). In addition, a large class size tends to cause administrative burden associated with delivering traditionally invigilated exams, running laboratory classes and marking (Gibbs & Jenkins, 1992; Biggs & Tang, 2011; Vista et al., 2015). University educators have been actively developing more effective and flexible delivery models to provide students with access to quality learning experiences whilst simultaneously meeting institutional imperatives for efficiency and accountability (George–Walker & Keeffe, 2010).

The advent and continuous development of information and communication technology (ICT) in conjunction with 'digitally adept' generations in recent decades has changed the perception of the higher education student experience. Blended learning is one of the fastest growing trends in university education as it offers flexibility for students to access course content and instruction at any time and from any place, as well as the ability to replay and revisit visual forms of learning resources (Henderson et al., 2017). The importance of learning resources to enhance student engagement has also been emphasised (Wingard, 2004; Dziuban et al., 2011; Delialioglu, 2012). A further benefit using blended delivery is an increase in interaction and engagement between students by communication through online forums (Chen & Looi, 2007; Roger, 2011). Hybrid approaches which combine face-to-face learning with online learning have become an important trend in recent years (Graham et al., 2013; Means et al., 2013; Alammary et al., 2014; Porter et al., 2016). Studies have found that blended approaches do not eliminate the need for a face-to-face instructor, which is still regarded as necessary for engineering education, but are more effective than a traditional face-to-face delivery mode (Means et al., 2013; Henderson et al., 2017). Effects of the change in the delivery mode from traditional to blended learning have been measured by various methods in the literature, including student academic performance (Deperlioglu & Kose, 2013; Kwak et al., 2015), student feedback and survey (Deperlioglu & Kose, 2013; Chen et al., 2015; Choy & Quek, 2016; Al-Azawei et al., 2017), and teaching staff feedback and self-evaluation (Boelens et al., 2018).

Although blended learning has been readily available for many years, there is great diversity in the implementation of blended delivery across many universities, ranging from basic use of a learning management system for file storage, to full development of online and distance education courses with recorded and interactive lectures, online communication and discussion group forums, electronic submission and marking of assessments, and further technology-enhanced learning activities. The motivation of the current paper is to describe the extensive implementation of a range of blended learning and delivery activities for the lectures, assessments, student query and administration within a mechanics course that had previously been delivered with traditional approaches.

The School of Mechanical and Manufacturing Engineering at the University of New South Wales (UNSW) offers multiple four-year Bachelor degree specialisations including mechanical, mechatronics, aerospace and manufacturing engineering. Before undergraduate students enter their specific specialisation in the third year of their degree, all students within the school are required to complete a second-year mechanics course that covers both dynamics and mechanical vibration content. The traditional delivery of this course involved face-to-face lectures, break out smaller-sized face-to-face tutorial classes, hands-on laboratory exercises in very small groups supervised by a teaching assistant, and a variety of assessments comprising assignments, class tests, laboratory reports and a final exam. All assessments were submitted and marked in hardcopy format. However, the structure and delivery of the course has been severely challenged by fast growing enrolment numbers corresponding to 10-15% increase in class size each year. The ability to deliver the assessment activities during the semester was also substantially challenged by changes in learning and teaching policies. In 2016, the UNSW Faculty of Engineering introduced a new policy for a consistent turnaround time of marked assessments to be returned to students. The policy requires that an assessment task worth equal to or less than 10% of the total course mark should be marked and returned within one week. An outcome of this institutional policy is the increased pressure on the lecturers and teaching assistants of large class sizes to mark hardcopy assessments in the given time frame. To deal more efficiently with the administration of the large mechanics class, reduce the burden on the teaching assistants, comply with the new faculty policy constraints to deliver feedback on assessments within a given time frame, and most importantly, maintain student engagement and participation in the learning activities throughout the semester, the lecturers developed an extensive range of blended learning and delivery activities. Significant changes were implemented for the interaction of students with the learning management system, delivery of the lecture content and the delivery and frequency of assessments. Students' academic performance in the traditional and blended modes is compared to evaluate the outcome of the online initiatives.

COURSE STRUCTURE, CONTENT AND ASSESSMENTS

At UNSW, a compulsory course undertaken by undergraduate students in the School of Mechanical and Manufacturing Engineering in the second year of their four-year Bachelor degree program comprises rigid body mechanics combined with mechanical vibration. The course, titled "MMAN2300 Engineering Mechanics 2", involves a weekly 5-hour period of face-to-face contact corresponding to 3 hours of lectures and 2 hours of tutorial classes. Additional contact hours are scheduled for the two laboratory classes during the semester.

The course content is separated into two parts, comprising Part A: Vibration Analysis and Part B: Plane Kinematics and Kinetics of Rigid Bodies. The course topics are summarised in Table 1. Each part is delivered for the same duration of six weeks each, and each part has the same assessment structure. The learning outcomes for the course were developed to address multiple factual and conceptual knowledge

Table 1. Course topics in the second year mechanics course.

Part A: Vibration Analysis	– Introduction to mechanical vibration – Free vibration of a single DOF spring-mass-damper – Logarithmic decrement
	– Forced harmonic vibration – Rotating unbalance – Base excitation
	– Free vibration of a 2-DOF system
	– Forced harmonic vibration of 2-DOF system
	– Distributed parameter systems; Transverse vibration of a string, longitudinal vibration of a bar
Part B: Plane Kinematics and Kinetics of Rigid Bodies	– Velocity analysis
	– Methods of instant centres
	– Acceleration analysis – "Coriolis type" problems
	– Kinetics of rigid bodies
	– Gears and gear analysis

and skills on the basis of the revised Bloom's Taxonomy (Krathwohl, 2002) and the Australian Qualifications Framework (Australian-Qualifications-Framework-Council, 2013). These learning outcomes are:

1. Explain and apply principles and components of Engineering Mechanics using a range of techniques.
2. Explain and describe principles and components of mechanical vibrations. Principles and components include mass, stiffness, damping, natural frequencies, harmonic excitation, isolation, single and multi-degree-of freedom systems, and continuous systems.
3. Discern the relevant principles that must be applied to describe the equilibrium or motion of engineering systems and discriminate between relevant and irrelevant information in the context.
4. Demonstrate an ability to communicate clearly and precisely about technical matters related to Engineering Mechanics.
5. Accomplish hands-on tasks that require the application of knowledge of Engineering Mechanics.

The mechanics course has the same learning outcomes for its delivery in traditional and blended mode. To assess the successful delivery of these learning outcomes, a range of assessment activities as well as a final exam are undertaken by all students. The old and new assessment structures for the course are given in Table 2. The learning outcomes assessed for each assessment activity are also listed in Table 2. The assessments within the old structure comprised of test papers, assignments, individual laboratory reports and the final examination paper, whereby all assessments were submitted as hardcopy documents. The new assessment structure for the course incorporating online activities is listed in Table 2(b), in which only the class tests and final examination are hardcopy papers. In the new structure, the online quizzes and laboratory reports were assessed within the learning management system. Table 3 presents

Table 2. Old (a) and new (b) assessment structure, weighting and learning outcomes assessed for the second year mechanics course.

	Assessment task	Weighting	Learning Outcomes
(a) Old	4 x class tests	20% (5% each)	1, 2, 3, 4
	2 x assignments	10% (5% each)	1, 2, 3, 4
	2 x laboratory tasks	20% (10% each)	1, 2, 4, 5
	Final examination	50%	1, 2, 3, 4
(b) New	4 x class tests	20% (5% each)	1, 2, 3, 4
	12 x Moodle quizzes	24% (2% per week)	1, 2, 3, 4
	2 x laboratory tasks	16% (8% each)	1, 2, 4, 5
	Final examination	40%	1, 2, 3, 4

Table 3. Traditional and blended delivery structures of the second year mechanics course.

Traditional mode	Blended mode
3 hours lectures face-to-face per week	3 hours lectures face-to-face per week + recorded lectures + 6 online interactive modules on lecture topics
2 hours tutorial face-to-face per week	2 hours tutorial face-to-face per week
2 x 1 hour laboratory classes	2 x ½ hour laboratory classes
4 x class tests (1 hour each)	4 x class tests (1 hour each)
Weekly tutorial problems in PDF form (all students have identical numbers; generic solutions posted in PDF form 1 week after tutorial)	Online tutorial problems (all students have different numbers; online generic solutions available after 2 incorrect attempts)
2 x Assignments (submitted in hardcopy)	12 x Moodle quizzes
Final examination (3 hours)	Final examination (2 hours)

the traditional and blended delivery structures of the mechanics course. The lecture and tutorial contact time for students was unchanged in the transition from traditional to blended mode. The contact time for the class tests was also unchanged. The contact time for the two laboratory activities reduced from one hour to half an hour per group. The duration of the final examination was also reduced from 3 hours to 2 hours, arising from a new university-wide policy introduced in 2016 requiring that the maximum duration of the formal, centrally administered examination for a course at the end of a semester is 2 hours.

BLENDED LEARNING AND DELIVERY

Digital uplift funds of AUD $25,000 (~ USD $17,000) were provided by the Office of the Pro Vice Chancellor Education (PVCE) of UNSW. The digital uplift program ran over a six month period in 2016 and was coordinated by two project managers of the Office of the PVCE. The personnel involved in the digital uplift for the mechanics course comprised the two project managers, the three lecturers of the course (the authors of this paper), and three teaching assistants. The team met weekly for one hour for the first two months, during which time the tasks to be carried out within the digital uplift project were identified, and a budget and timeline for completion of the tasks established. The team then met weekly for half an hour for the remainder of the digital uplift program to assess progress of the various activities. Outside these scheduled meetings, the lecturers were involved in reviewing all tasks during their various stages of completion. The project managers also organised additional technical support for the filming and editing of the pre-laboratory videos, animation and graphics design for the lecture material and online problems, and website instructional design for the online interactive lessons. The following blended learning and delivery activities were developed for implementation within the Moodle learning management system:

1. Redesign of the learning management system interface;
2. Development of online interactive lecture modules on specific topics;
3. Development of online tutorial problems and weekly assessed quizzes;
4. Development of online laboratory activities including pre-laboratory video lessons.

The online initiatives are described in more detail in what follows.

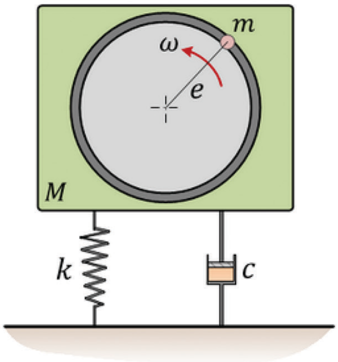
Redesign of the Learning Management System Interface

The Moodle page for the mechanics course historically consisted of separate sections with the headings of Lecture Notes, Tutorial Problems, Assignments, and Labs. Within each of these sections, relevant PDF files were located. No other files or activities existed within the learning management system. The redesign of the Moodle page involved creating sections by dividing the course into weeks, then itemising the activities within each week in a consistent format. Clear instructions were provided to students of their commitments for that week in a consistent format, comprising links to PDF files of the detailed lecture notes, lecture recordings, PDF files of the lecture PowerPoint slides, lecture modules on specific topics, online tutorial problems, weekly quizzes, laboratory pre-work and the laboratory online booking and submission systems. A snapshot of a typical weekly section is shown in Figure 1.

Development of Lecture Material Modules

Six lecture material modules were developed for students to access at any time independently of their scheduled weekly lectures. Two pre-lecture modules were developed as refresher material from the prerequisite first year mechanics course, corresponding to (1) Velocity analysis and (2) Acceleration analysis. Four post-lecture modules were developed to reinforce lecture material by including key learning outcomes as well as worked examples. The topics of the post-lecture modules comprised the (3) Instant centre method, (4) Vibration absorbers, (5) Vibration isolators, (6) Modeshapes for discrete and continuous parameter systems. Example screenshots of a pre-lecture module and a post-lecture module are shown in Figures 2 and 3, respectively.

Week 2 - Forced Harmonic Vibration of SDOF systems



Forced Harmonic Vibrations

- Some classifications

Forced Vibrations due to

- Rotating unbalance
- Base excitation

Vibration Isolation

- Theory
- Vibration isolators

Read your lecture notes for week 2: Week 2 Lecture Notes (Part A, Unit 2)

Attend the lectures for Week 2 on Monday 10am-12pm and Wednesday 12-1pm in Ainsworth G03

Watch the video recording of Week 2 Lecture 1

echo Week 2 Lecture 1

Watch the video recording of Week 2 Lecture 2

echo Week 2 Lecture 2

Lecture slides for week 2: Week 2 Lecture Slides

Attend your problem solving session at your scheduled time (check timetable; campus map)

Vibration Isolation lesson

Lab 1 - Rotating Mass Unbalance Pre-Laboratory Lesson

In the link above you will find the following information needed for your Rotating Mass Unbalance lab.

- Laboratory safety requirements
- Video
- Safety declaration
- Book your lab time slot

Online tutorial problems for week 2: Part A Tutorial 2

Moodle Quiz 1 - due Friday 3 August 5:00pm

Figure 1. Week 2 of the MMAN2300 Engineering Mechanics 2 course in Moodle.

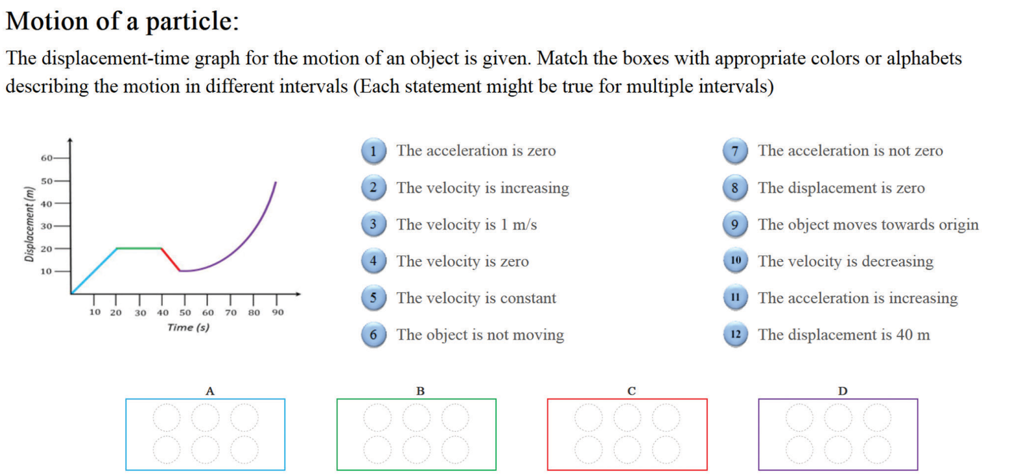


Figure 2. Slide from pre-lecture module on velocity analysis.

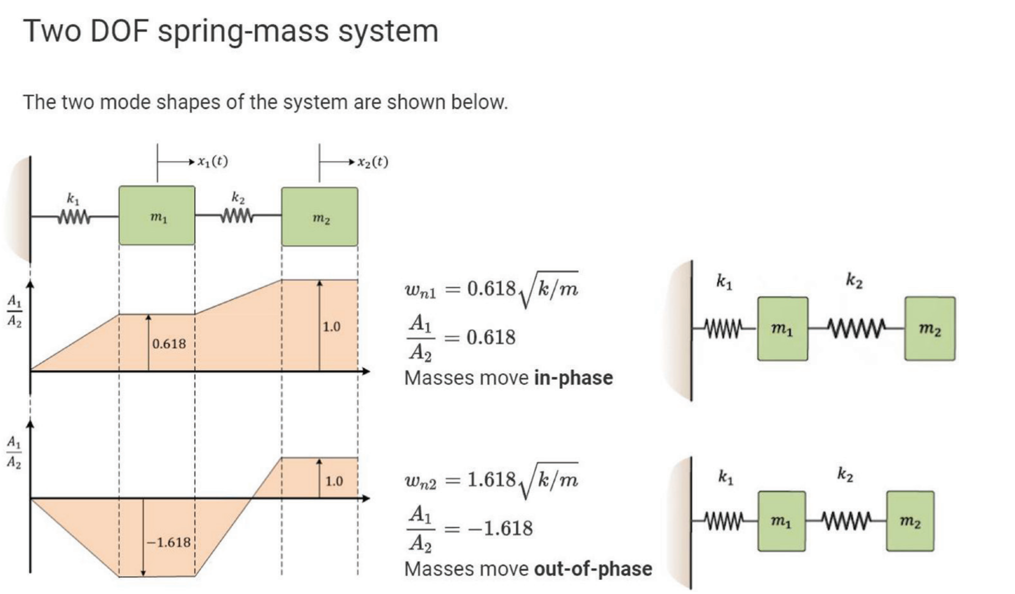


Figure 3. Slide from post-lecture module on modeshapes of a two degree-of-freedom spring-mass system.

Development of Online Problems

Online problems have been identified as an effective component in blended learning that provides feedback to students as well as enhances the flexibility around the time and place of undertaking the online assessment task (Gikandi et al., 2011; Spanjers et al., 2015). Based on the tutorial and assignment problems in the traditional delivery of the mechanics course, a series of online problems using Moodle STACK (System for Teaching and Assessment using a Computer algebra Kernel) were developed. These questions were embedded in the Moodle question bank for all topics covered in the course. STACK uses Maxima as a back-end calculation engine, allowing the generation of random problem variables and calculation of complex mathematical expressions. STACK also allows evaluation of student answers whether they are numerical, algebraic (symbolic), selected from a drop-down list or several other answer types. For the online problems, all students have identical problems with different values for key variables chosen from a dataset of pre-set values. This feature created individual numerical problems for each student. These individual numerical problems provided students with a modest challenge in a self-test environment with immediate feedback.

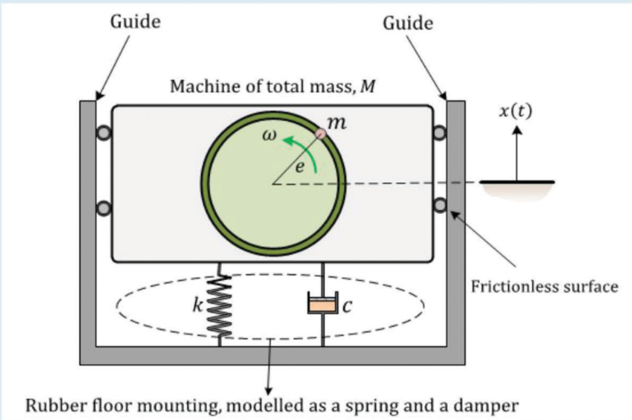
A total of 220 problems were programmed and aligned with the lecture content. The majority of the problems were provided as weekly non-assessed tutorial problems, with the remainder used for the weekly quizzes. The non-assessed problems were designed to provide foundation understanding of the lecture material. Within a given topic, the online problems gradually increase in difficulty. Students were encouraged to attempt the online problems in increasing consecutive order, with the aim to build student confidence. To encourage students' participation, a bonus mark of 2% was given for completion of all the online tutorial problems. An example of an online tutorial problem is shown in Figure 4(a). The corresponding generic solution in terms of coefficients for the random variables is shown in Figure 4(b). Generic solutions for the online tutorial problems became available to students after two incorrect attempts. As such, the individual numeric problems provided students with a modest challenge in a self-test environment with immediate feedback.

The assessed online weekly quizzes were set up as a formative assessment. Students were given access to all weekly quizzes from the beginning of the semester with unlimited attempts to get the correct answer without a loss of marks for incorrect attempts before the due date for a given quiz. Solutions for the quiz problems were not provided. The full mark for a quiz problem was awarded for a correctly answered problem before its due date. As such, the majority of students performed well for this assessment activity, as shown later in the section Academic Performance. However, it is the authors' intention to convert this formative assessment activity into a summative assessment by placing a time restriction on the quizzes. The rationale for this arrangement is also described later in the paper.

Development of Online Laboratory Activities

A significant online component for the two laboratory tasks was implemented, including (1) development of an online video for laboratory pre-work, (2) development of an online laboratory booking system, and (3) development of an online report submission and marking system. For the laboratory pre-work, the students were required to watch a video recording of the laboratory task which described the instrumentation, safety hazards, procedure, learning outcomes and reporting requirements (see

A typical unbalanced machine is shown in the figure below. The machine has mass of 120 kg, a mount stiffness of 1300 kN/m, and a damping value of 550 kg/s. The amplitude of the out-of-balance force is measured to be 336 N at a running speed of 2900 rev/min. Determine the amplitude of motion due to the out of balance.



Answer:

Check

(a)

Mass of the machine = M (kg)

Spring constant = k (N/m)

Damping constant= c (kg/s)

The amplitude of the out-of-balance force= F_O (N)

Running speed= ω ($\frac{\text{rev}}{\text{min}} \times \frac{2\pi}{60}$= rad/s)

The out-of-balance force is due to rotating unbalance => $F_O = me\omega^2$

$$=> me = \frac{F_O}{\omega^2}$$

$$\omega_n = \sqrt{\frac{k}{M}} \text{ (rad/s)}$$

$$\frac{MX}{me} = \frac{\left(\frac{\omega}{\omega_n}\right)^2}{\sqrt{\left[1-\left(\frac{\omega}{\omega_n}\right)^2\right]^2+\left(2\zeta\frac{\omega}{\omega_n}\right)^2}}$$

$$=> X = \frac{me\left(\frac{\omega}{\omega_n}\right)^2}{M\sqrt{\left[1-\left(\frac{\omega}{\omega_n}\right)^2\right]^2+\left(2\zeta\frac{\omega}{\omega_n}\right)^2}} \text{ (m)}$$

is the amplitude of motion due to the out of balance.

(b)

Figure 4. (a) An online tutorial problem in the vibration part of MMAN2300 Engineering Mechanics 2 and (b) the corresponding generic solution for (a).

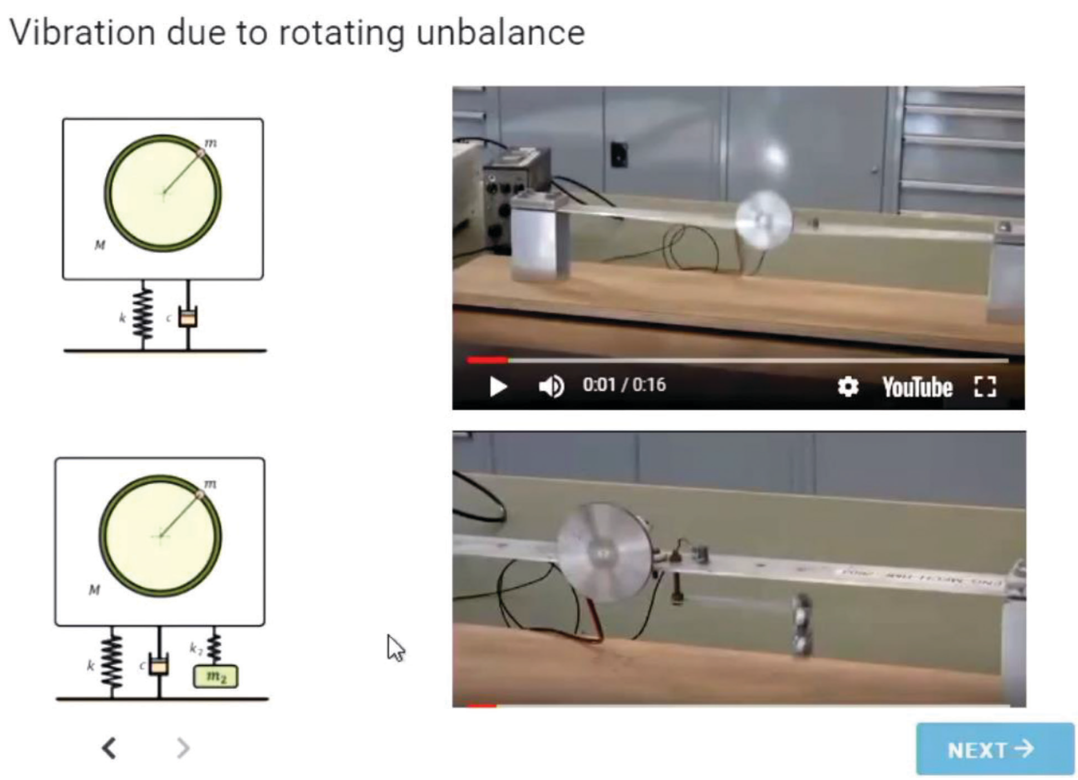


Figure 5. Snapshot of the video recording for laboratory task 1 on the topic of vibration generated by rotating unbalance.

Figure 1 for a list of the pre-work for the first laboratory exercise, as displayed in the learning management system). A snapshot of the video recording is shown in Figure 5. After watching the video, the students were directed to a link to read the Risk Management Form associated with the laboratory task (see Figure 6). After students had declared the safety form as read, they were then directed to an online laboratory booking system, in which they could enrol themselves into a pre-established time slot of their convenience for the hands-on component of the laboratory task. The online laboratory booking system automatically emailed students with a calendar invite of their chosen time slot. An online report submission system was set up in which the laboratory reports were submitted via Turnitin, a plagiarism detection software. An online rubric for marking the laboratory reports was also developed. The marking rubric was made available to students to allow them to identify what was required to achieve a certain grade. An example of feedback provided on a laboratory report using the online marking rubric is shown in Figure 7. All the aforementioned online initiatives associated with the laboratory activities were implemented in the Moodle learning management system.

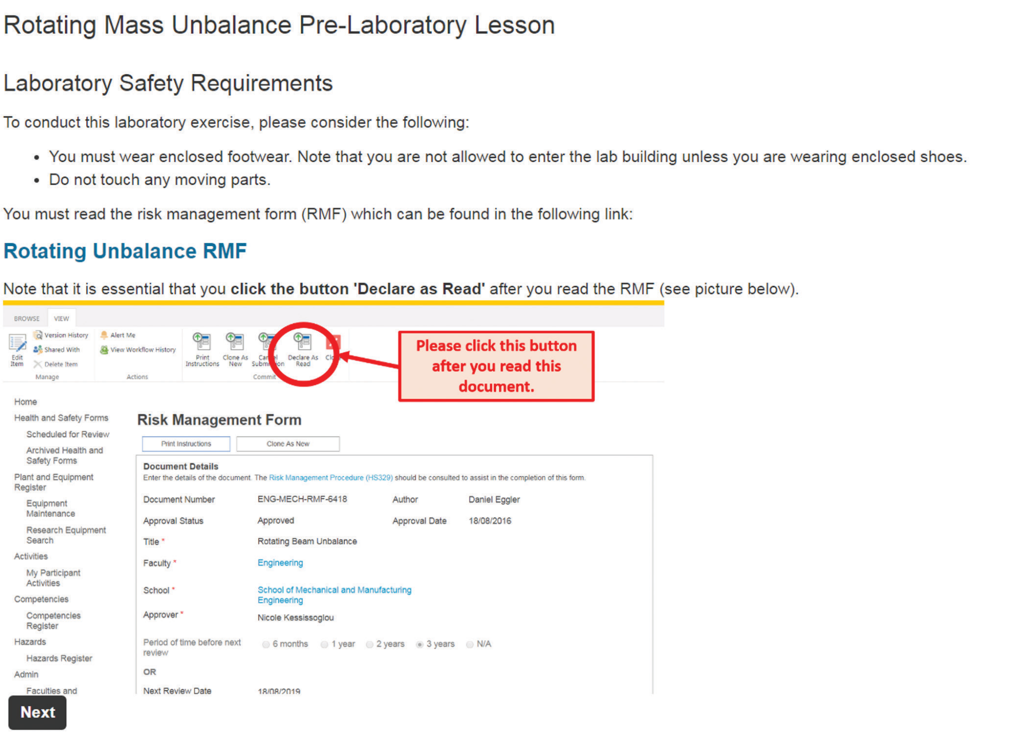


Figure 6. Snapshot of the risk management form (RMF) associated with Laboratory 1.

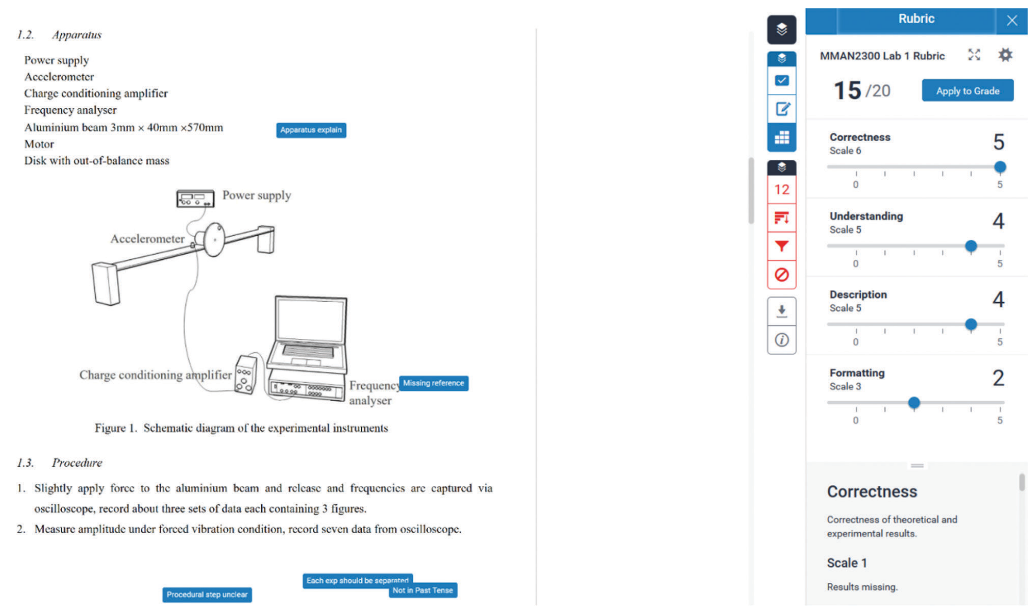


Figure 7. Snapshot of feedback for a Laboratory 1 report.

DISCUSSION

The efficacy of blended learning on course administration, student engagement and students' academic performance in the years 2016 to 2018 are compared with those in 2015 associated with traditional delivery prior to the implementation of the blended learning activities.

Improved Administration

There was significant impact arising from the implementation of the various online initiatives. First, the online laboratory booking system dramatically reduced administrative burden associated with manual booking of the students' laboratory time slot and ensuring that all students had signed the risk management form before attending each lab. Second, the pre-laboratory video reduced the laboratory contact time with teaching assistants by 50%, from one hour to half an hour per group as shown in Table 3. This reduction in laboratory contact time also improved timetabling administration, where the hands-on component for each laboratory exercise could be delivered within one week for all groups instead of delivered over a two-week period. Implementation of the pre-laboratory video also resulted in an enormous reduction in the number of inquiry emails regarding the laboratory tasks as well as reduced variability in the information provided to students from the teaching assistants. Since students were no longer required to submit a hardcopy of the safety declaration form and their laboratory report, there was a dramatic reduction in paper waste. The online submission system also eliminated cases where students claimed they had submitted a (hardcopy) report but it could not be located. Further, submission of the individual laboratory reports via Turnitin allows plagiarism to be detected and the seriousness of the plagiarism to be easily assessed. Online implementation of the detailed rubric for marking of the laboratory reports provided greater consistency across teaching assistants in marking the laboratory reports, as well as significantly reduced the time taken to mark the reports. A further impact arising from the implementation of blended delivery of the laboratory activities was the reduction in the financial cost of running the laboratory exercises due to a reduction in contact time for the hands-on component and marking.

The two assignments in the old course structure were replaced with 12 online quizzes, as shown in Tables 2 and 3. The quizzes were automatically marked in Moodle STACK, resulting in a reduction in financial cost associated with marking. Replacing the assignments with online quizzes also eliminated administration issues dealing with handling large quantities of paper and misplaced assignments. Further, there was no need to try and return marked assessments back to students, which often took substantial time over several attempts in lectures, tutorials and during consultation time. Hardcopy assessments were never collected by many students. Finally, for both the online laboratory reports and quizzes, there was no need for data entry of students' marks.

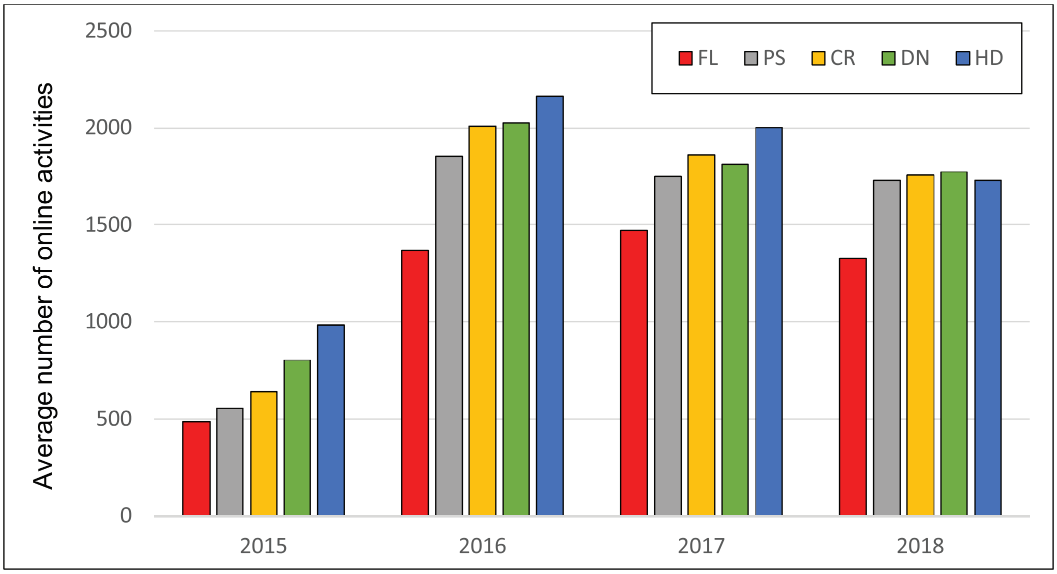


Figure 8. Average number of activities per student in the learning management system for a given grade in the mechanics course in 2015 (traditional mode) and 2016-2018 (blended mode).

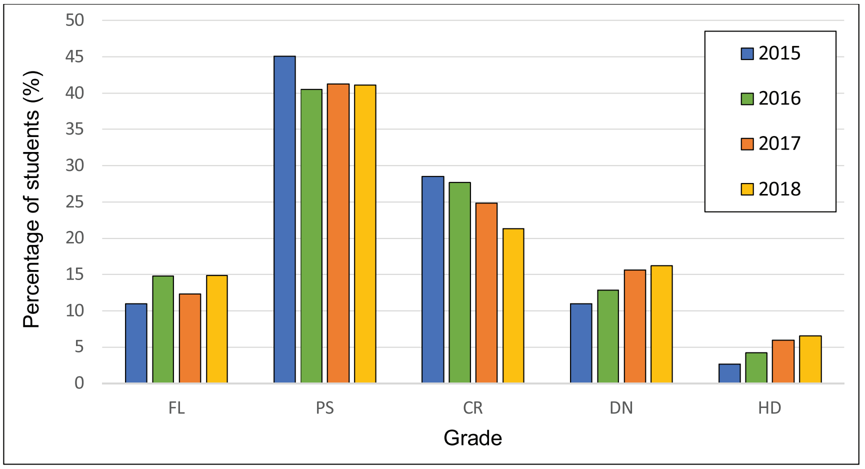
Student Engagement

Student engagement in the Moodle learning management system was herein quantified by means of monitoring the number of activities in Moodle, and includes both passive activities (viewing and clicking) and active activities (posting and submission). The average number of activities per student increased almost threefold with the implementation of blended learning. Figure 8 presents the average number of online activities per student in the learning management system for a given grade for traditional delivery (in 2015) and blended delivery (years 2016–2018). The course grades range from 85-100% for high distinction (HD), 75–84% for distinction (DN), 65–74% for credit (CR), 50-64% for pass (PS), and fail (FL) below 50%. A correlation between student engagement with the online resources and their performance can be observed, whereby the number of online activities of students who failed the mechanics course is significantly lower than that of students in other grades.

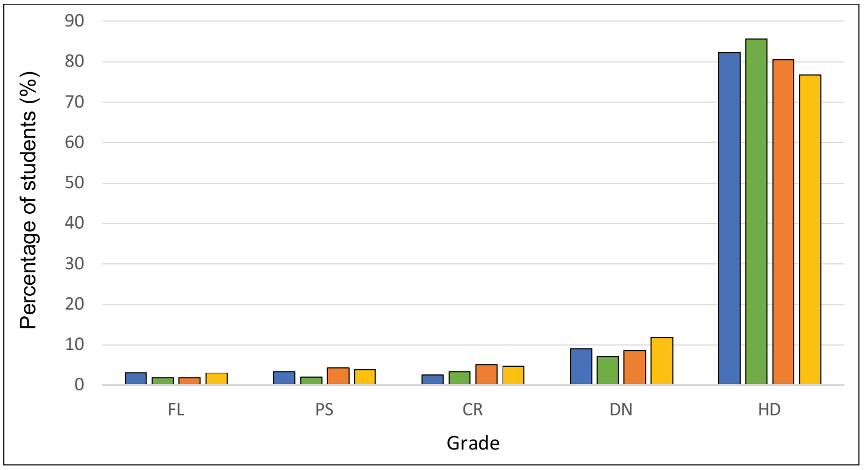
Academic Performance

The total course grade as well as the grades for the individual assessments listed in Table 2 are herein discussed. The total course grade comprises summation of the marks of the assessments items in Table 2(a) for traditional delivery (in 2015), and in Table 2(b) for the blended delivery (2016 onwards). Figure 9(a) shows that after implementation of the blended activities, a slightly higher percentage of students failed the course compared with the traditional delivery in 2015. However, the failure grades are all within 10-15%, showing no significant difference, and is below the failure rate in the 20-40% range in engineering mechanics courses reported in Australia universities (Goldfinch et al., 2009). Based on the UNSW Faculty of Engineering practice and expectation, a 10-15% failure rate is an acceptable failure rate for a second-year large sized undergraduate course. The percentages of students that achieved a pass grade (PS) are marginally lower for the blended delivery than for the traditional delivery. In contrast, Figure 9(a) shows that the percentages of students who achieved distinction (DN) and high distinction (HD) slightly increased. Based on this data collected over the four-year period, we observe that implementation of the blended learning and assessment activities had a marginal effect on the low achieving students (those who achieve grades of FL and PS), while a noticeable effect can be observed on the middle grade (CR) students moving towards higher grades. A similar trend showing that blended delivery is more effective for the higher achieving student group was report by Asarta and Schmidt (2017).

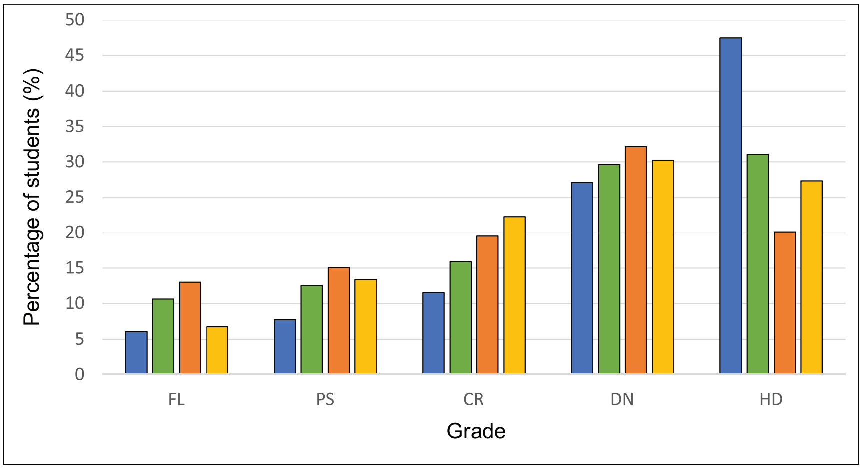
The students' grades for the individual assessments and final examination are now examined. Figure 9(b) presents the percentage of students who achieved a given grade for the assignments (in 2015) and online quizzes (2016–2018). Both these assessments were formative assessments, for which students had at least two weeks to complete the assessment task and were able to seek assistance from their peers. Figure 9(b) shows that the vast majority of students achieved high distinction for these assessment activities. Whilst the high grade for the quizzes reflects the high motivation of students to get full marks for this assessment activity, it does not necessarily reflect their understanding of the course material. Figure 9(c) presents the student performance in the laboratory activities. Prior to the implementation of the marking rubric, the majority of students achieved an HD grade, attributed to lack of guidance provided to the teaching assistants for marking of the laboratory reports. The students' performance in the invigilated tests and final examination are presented in Figures 9(d) and (e), respectively. Figure 9(d) shows no significant change in students' performance in the tests, where historically, students have performed poorly. Despite slight fluctuations in each grade, its trend in the percentage distribution remains uniform in all years. Surprisingly, Figure 9(d) shows that the failure rates of the final exam doubled from around 30% in 2015 (traditional delivery) to around 60% in the years 2016 to 2018 (blended delivery). Exam results are a strong measure of students' understanding and one of the most popular ways of evaluating the effectiveness of blended delivery across a range of disciplines, for example, see Pereira et al. (2007), Bergtrom (2011), Albert and Beatty (2014) and Baepler et al. (2014). As such, the data shown in Figure 9(e) indicates that the online assessment activities implemented for the mechanics course has not improved student academic performance in the summative assessments. Measures to address this issue are proposed in what follows.



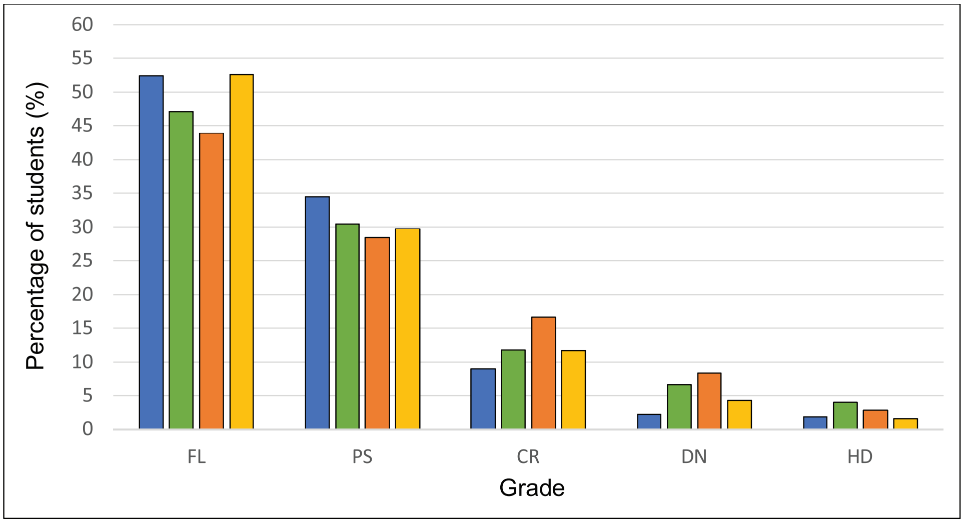
(a) Total course



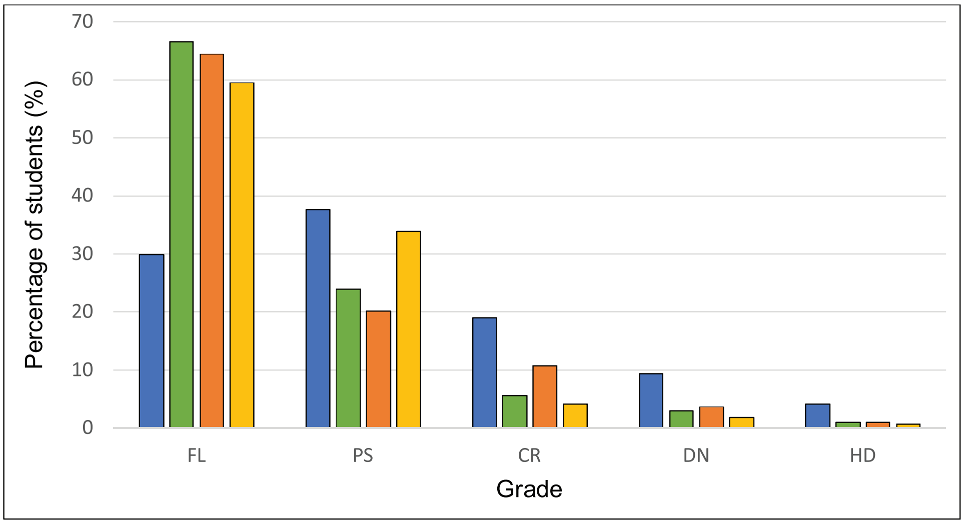
(b) Assignments (2015) and quizzes (2016-2018)



(c) Laboratory tasks



(d) Class tests



(e) Final examination

Figure 9. Percentage of students who achieved a given grade in the mechanics course in 2015 (traditional mode) and 2016–2018 (blended mode) for (a) the total course, (b) assignments (2015) and quizzes (2016–2018), (c) laboratory tasks, (d) class tests, and (e) final examination.

The poor performance in the tests and final examination for the course delivered in blended mode has made us reflect on our assessment design and identify areas for improvement. As a first step, we will convert the online quizzes from a formative assessment to a summative assessment, to more accurately reflect student academic performance for this assessment activity. This will be achieved by placing a time restriction of one hour for each weekly quiz. Implementation of the time restriction on the quizzes needs to be term-planned in the course timetable to avoid class clashes with other courses. We will monitor if the time restriction on the quizzes provides students with better ability for self-assessment and progressive learning.

SUMMARY AND CONCLUSIONS

Engineering mechanics is a core course for mechanical engineering students and has been identified as one of the most challenging courses in the undergraduate program. The course underwent a major digital uplift over a six-month period that included (i) redesign of the learning management system interface, (ii) development of online interactive lecture modules on specific topics, (iii) development of online tutorial problems and weekly assessed quizzes, and (iv) development of online laboratory activities that included pre-laboratory video recordings, an online report submission system and an online marking rubric. Implementation of the various online activities was shown to significantly increase student engagement with the online resources. Further, implementation of the online activities dramatically reduced administrative burden associated with the delivery of the course, mainly associated with the laboratory activities and replacement of the hardcopy assignments with the online quizzes. Whilst there was a significant financial investment to implement the various online initiatives in the mechanics course, there were immediate significant financial savings in running the laboratory activities and marking. Student academic performance in the course was not shown to improve. Actions to attempt to improve student performance will be implemented for future delivery of the course.

REFERENCES

Al-Azawei, A., Parslow, P. & Lundqvist, K. (2017). Investigating the effect of learning styles in a blended e-learning system: An extension of the technology acceptance model (TAM). *Australasian Journal of Educational Technology* 33 (2):1–23. https://doi.org/10.14742/ajet.2741

Alammary, A., Sheard, J. & Carbone, A. (2014). Blended learning in higher education: Three different design approaches. *Australasian Journal of Educational Technology* 30 (4):440–54. https://doi.org/10.14742/ajet.693

Albert, M. & Beatty, B. J. (2014). Flipping the Classroom Applications to Curriculum Redesign for an Introduction to Management Course: Impact on Grades. *Journal of Education for Business* 89 (8):419–24. https://doi.org/10.1080/08832323.2014.929559

Asarta, C. J. & Schmidt, J. R. (2017). Comparing student performance in blended and traditional courses: Does prior academic achievement matter? *The Internet and Higher Education* 32:29–38. https://doi.org/10.1016/j.iheduc.2016.08.002

Australian-Qualifications-Framework-Council. (2013). Australian Qualification Framework. Retrieved from https://www.aqf.edu.au/sites/aqf/files/aqf-2nd-edition-january-2013.pdf.

Baepler, P., Walker, J. D. & Driessen, M. (2014). It's not about seat time: Blending, flipping, and efficiency in active learning classrooms. *Computers & Education* 78:227–36. https://doi.org/10.1016/j.compedu.2014.06.006

Bergtrom, G. (2011). Content vs. learning: An old dichotomy in science courses. *Journal of Asynchronous Learning Network* 15 (1):33–44. Retrieved from https://eric.ed.gov/?id=EJ918217

Biggs, J. B. & Tang, C. (2011). *Teaching for Quality Learning at University : What the Student Does, Society for Research into Higher, Education*. Maidenhead, UK: Open University Press.

Boelens, R., Voet, M. & De Wever, B. (2018). The design of blended learning in response to student diversity in higher education: Instructors' views and use of differentiated instruction in blended learning. *Computers & Education* 120:197–212. https://doi.org/10.1016/j.compedu.2018.02.009

Chen, L., Chen, T.-L. & Chen, N.-S. (2015). Students' perspectives of using cooperative learning in a flipped statistics classroom. *Australasian Journal of Educational Technology* 31 (6):621–40. https://doi.org/10.14742/ajet.1876

Chen, W. & Looi, C.-K. (2007). Incorporating online discussion in face to face classroom learning: A new blended learning approach. *Australasian Journal of Educational Technology* 23 (3):307–26. https://doi.org/10.14742/ajet.1255

Choy, J. L. F. & Quek, C. L. (2016). Modelling relationships between students' academic achievement and community of inquiry in an online learning environment for a blended course. *Australasian Journal of Educational Technology* 32 (4):106–24. https://doi.org/10.14742/ajet.2500

Delialioglu, O. (2012). Student Engagement in Blended Learning Environments with Lecture-Based and Problem-Based Instructional Approaches. *Educational Technology & Society* 15 (3):310–22. Retrieved from https://eric.ed.gov/?id=EJ992563

Deperlioglu, O. & Kose, U. (2013). The effectiveness and experiences of blended learning approaches to computer programming education. *Computer Applications in Engineering Education* 21 (2):328–42. https://doi.org/10.1002/cae.20476

Dziuban, C., Hartman, J., Cavanagh, T. B. & Moskal, P. D. (2011). Blended Courses as Drivers of Institutional Transformation. In *Blended Learning across Disciplines: Models for Implementation*, 17–37. Hershey, PA, USA: IGI Global.

George–Walker, L. D. & Keeffe, M. (2010). Self–determined blended learning: a case study of blended learning design. *Higher Education Research & Development* 29 (1):1–13. https://doi.org/10.1080/07294360903277380

Gibbs, G. (1992). Control and independence. In *Teaching large classes in higher education: How to maintain quality with reduced resources*, edited by Graham Gibbs and Alan Jenkins, 37-62. London, UK: Kogan Page Limited.

Gibbs, G. & Jenkins, A. (1992). An introduction: the context of changes in class size. In *Teaching large classes in higher education: How to maintain quality with reduced resources*, edited by Graham Gibbs and Alan Jenkins, 11–22. London, UK: Kogan Page Limited.

Gikandi, J. W., Morrow, D. & Davis, N. E. (2011). Online formative assessment in higher education: A review of the literature. *Computers & Education* 57 (4):2333–51. https://doi.org/10.1016/j.compedu.2011.06.004

Goldfinch, T., Carew, A. L. & Thomas, G. (2009). Students views on engineering mechanics education and implications for educators. *Proceedings of 20th Australasian Association for Engineering Education Conference*:624–9. Retrieved from https://ro.uow.edu.au/engpapers/528/

Graham, C. R., Woodfield, W. & Harrison, J. B. (2013). A framework for institutional adoption and implementation of blended learning in higher education. *The Internet and Higher Education* 18:4–14. https://doi.org/10.1016/j.iheduc.2012.09.003

Henderson, M., Selwyn, N. & Aston, R. (2017). What works and why? Student perceptions of 'useful' digital technology in university teaching and learning. *Studies in Higher Education* 42 (8):1567–79. https://doi.org/10.1080/03075079.2015.1007946

Krathwohl, D. R. (2002). A Revision of Bloom's Taxonomy: An Overview. *Theory Into Practice* 41 (4):212–8. https://doi.org/10.1207/s15430421tip4104_2

Kwak, D. W., Menezes, F. M. & Sherwood, C. (2015). Assessing the Impact of Blended Learning on Student Performance. *Economic Record* 91 (292):91–106. https://doi.org/10.1111/1475-4932.12155

Means, B., Toyama, Y., Murphy, R. & Baki, M. (2013). The effectiveness of online and blended learning: A meta-analysis of the empirical literature. *Teachers College Record* 115 (3):1–47. Retrieved from https://www.tcrecord.org/content.asp?contentid=16882

Mulryan-Kyne, C. (2010). Teaching large classes at college and university level: challenges and opportunities. *Teaching in Higher Education* 15 (2):175–85. https://doi.org/10.1080/13562511003620001

Pereira, J. A., Pleguezuelos, E., Merí, A., Molina-Ros, A., Molina-Tomás, M. C. & Masdeu, C. (2007). Effectiveness of using blended learning strategies for teaching and learning human anatomy. *Medical Education* 41 (2):189–95. https://doi.org/10.1111/j.1365-2929.2006.02672.x

Porter, W. W., Graham, C. R., Bodily, R. G. & Sandberg, D. S. (2016). A qualitative analysis of institutional drivers and barriers to blended learning adoption in higher education. *The Internet and Higher Education* 28:17–27. https://doi.org/10.1016/j.iheduc.2015.08.003

Roger, B. M. (2011). Student Engagement with, and Participation in, an e-Forum. *Journal of Educational Technology & Society* 14 (2):258–68. Retrieved from https://eric.ed.gov/?id=EJ930255

Spanjers, I. A. E., Könings, K. D., Leppink, J., Verstegen, D. M. L., de Jong, N., Czabanowska, K. & van Merriënboer, J. J. G. (2015). The promised land of blended learning: Quizzes as a moderator. *Educational Research Review* 15:59–74. https://doi.org/10.1016/j.edurev.2015.05.001

Vista, A., Care, E. & Griffin, P. (2015). A new approach towards marking large-scale complex assessments: Developing a distributed marking system that uses an automatically scaffolding and rubric-targeted interface for guided peer-review. *Assessing Writing* 24:1–15. https://doi.org/10.1016/j.asw.2014.11.001

Wingard, R. G. (2004). Classroom Teaching Changes in Web-Enhanced Courses: A Multi-Institutional Study. *EDUCAUSE Quarterly* 27 (1):26–35. Retrieved from https://er.educause.edu/articles/2004/1/classroom-teaching-changes-in-webenhanced-courses-a-multiinstitutional-study

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