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Evaluation of Blended Learning Strategies from Exam Outcomes

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CONTEXT

The advantages of online course delivery include easy access to course content utilising multimedia tools to enhance the student educational experience, more rigorous control over course content, and data logging of student online interactions with course content. While higher educational institutions embrace the blended learning model, there are relatively few studies evaluating the effect of blended learning strategies on exam outcomes. We have developed a more objective evaluation procedure, based on statistical modelling the effect of student WAM (weighted average mark) and online lesson activity on exam outcomes.

PURPOSE

We wish to evaluate whether blended teaching strategies translate into better exam outcomes.

APPROACH

This retrospective study compares the effect of blended learning on exam outcomes with a historical control group. Exam scores for traditional face-to-face lectures (2012-2014) were compared to blended course delivery (2015-16). ANOVA was used to assess whether the change to blended learning affects exam outcomes. The effectiveness of online learning was quantified by correlating student online activity with exam outcomes.

RESULTS

Student WAM (weighted average mark) was the most significant predictor of final exam score. While there were significant differences between the exam results for each year, we were unable to detect an improvement in exam outcomes after introduction of blended learning. However online study time for each student was an independent predictor of final exam outcome.

CONCLUSIONS

While we did not detect an improvement in exam outcomes following introduction of online delivery of course content, WAM and online study time were predictors of final exam outcomes. The correlation between online study time and exam marks suggests that online activities were effective.

KEYWORDS

Blended learning, Biomechanics.

Introduction

Blended learning is defined as the delivery of content and instruction utilising online resources (Ruiz, Mintzer, & Leipzig, 2006). While face-to-face interactions are reserved for individualised instruction and problem solving, lectures and other content is delivered online using scripted or informal multimedia presentations contained within self-paced lessons with problem solving. The logging of student online interactions provides feedback for assessing the effectiveness of online content.

The application of blended learning strategies has grown with the availability of software for delivery of course content (e.g., Moodle, Blackboard). Despite the rapid growth in online learning, there are only a small number of randomised studies evaluating learning outcomes. The randomised study by Figlio and coworkers showed that students attending live lectures did 2-3 points better in exams compare to those assigned to online learning (Figlio, Rush, & Yin, 2013). In a similar randomised study by Joyce and coworkers there was no significant difference between face-to-face and online groups (Joyce, Crockett, Jaeger, Altindag, & O'Connell, 2015). A very large randomised study by Bowen (6 institutions, 605 subjects) had a similar conclusion to Joyce's study (Bowen, Chingos, Lack, & Nygren, 2014). The most recent randomised study by Alpert compared face-to-face class room, blended, and pure online course delivery (Alpert, Couch, & Harmon, 2016). They showed that exam scores were not different between class room and blended instruction, while student outcomes were consistently worse for the online teaching group. Given possible equivalence of blended learning and face-to-face teaching, other advantages of blended teaching models are student satisfaction and economising teaching resources through reduced instructor contact time in a class room setting (Alpert et al., 2016). Another potential advantage of online learning is to utilise recorded online learning activity to evaluate the effectiveness of teaching strategies. *A positive correlation between the time spent online and exam grades suggests that online activity was an effective learning strategy*.

The course "Biomechanics for Sports Scientists" delivered by the School of Biomedical Engineering teaches engineering mechanics to a non-engineering student with limited background in maths and physics. It is a core course delivered in the 2nd year of an undergraduate degree. A blended learning approach was adopted for the first time in 2015. While it was not possible to conduct a more randomised trial, it was possible to evaluate the introduction of blended learning retrospectively: Blended learning (2015 – 2016) was compared to a historical control group (2012 – 2014), where course content was delivered through traditional face-to-face lectures.

This study will address the following aims:

1. Evaluate the effect of blended learning on exam outcomes
2. Harvest online logging data for evaluation of online learning strategies
3. Identify predictors of student performance in exam

Methods

The Course

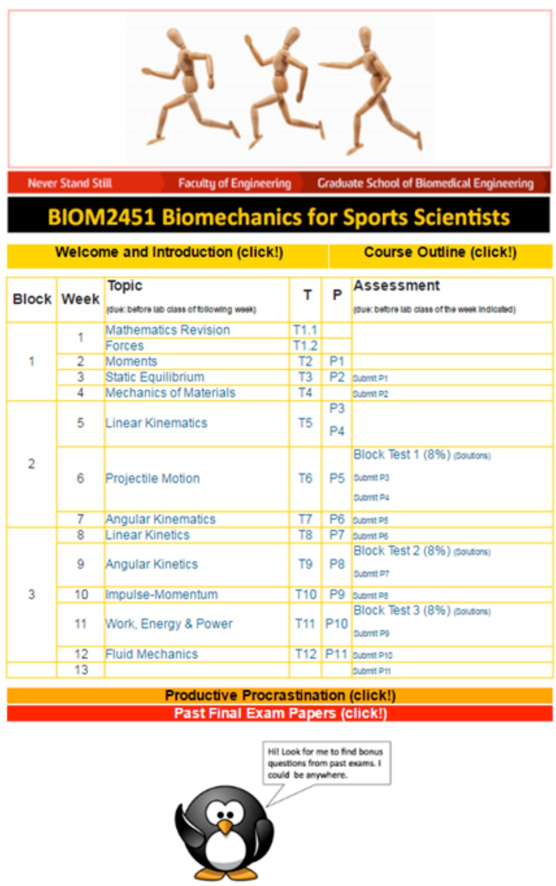
Biomechanics for Sports Scientists is a core course delivered in the second year of the Bachelor of Exercise Physiology program at UNSW. It is delivered by staff in the Faculty of Engineering to students enrolled in the Faculty of Medicine. It being interdisciplinary makes it a challenging course for all involved, but it also inspires the use of new learning and teaching strategies with the intent of improving the educational experience.

Biomechanics for Sports Scientists was designed according to the requirements of the appropriate professional body. It was structured in three blocks (Figure 1C), with blocks one and two containing the knowledge required to complete block three. This structure, as well as the course coordinator and lecturer, has been consistent since 2012.

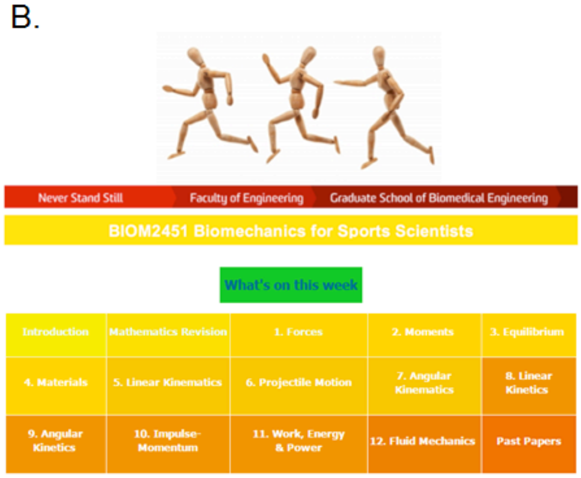
Prior to conversion to blended delivery, Biomechanics for Sports Scientists was delivered in a traditional format, where students attended face-to-face classes for a total of five hours per week, comprised of three one-hour lectures and a single two-hour laboratory class. In 2015, Biomechanics for Sport Scientists was converted to a blended course, where theoretical content is delivered online prior to the weekly face-to-face laboratory class (two hours per week).

Moodle was used for all years of this study. Between 2012 and 2014, it was used as a simple file repository where students could download lecture notes and laboratory instructions. This changed following conversion to blended delivery in 2015, and underwent further modifications in 2016. As shown in Figures 1A and 1B, the landing page of the course was converted into a graphical interface following the change to blended delivery. It was intended that students need only come to a single page to be able to find every piece of information required for the course. (Anecdotally, using learning management systems as file repositories can be overwhelming and confusing for a student.) The changes between 2015 and 2016 were made in response to student feedback, especially being able to find assessable items more easily and aiding in workload management and planning.

A.



B.



C.

Online Lesson	Block Test	Exam Question
Forces	1	1,2
Moments		1,2
Equilibrium		1,2
Mechanics of Materials	2	3
Linear Kinematics		5
Projectile Motion		5
Angular Kinematics		4
Linear Kinetics	3	5
Angular Kinetics		4
Impulse-Momentum	NA	6
Work, Energy and Power		7
Fluid Mechanics		NA

Figure 1 Summary of the course investigated. A: Online interface for 2016; B: Online interface for 2015; C: Course outline for all years (2012 – 2016), with a mapping of topics to final exam questions for the blended years (2015 and 2016).

The online content was designed to be a sort of digital textbook, delivered in small, digestible portions, using a variety of multimedia such as text, pictures and videos. In doing so, the theoretical content was identical to that which was delivered face-to-face in previous years, but students have control of pace and duration. All videos were restricted to a maximum of fifteen minutes, and copies of what was discussed in the video were also provided should the student prefer text-based information. In 2015, this was achieved using “Books” in Moodle. As the name suggests, it is possible to create an online book with chapters and sub-chapters for organisational purposes. Within the book you can embed any type of multimedia that is desired. To ensure students were making adequate progress, each book had a worksheet that the student was instructed to download and complete as s/he made his/her way through the content. At the end of the semester, if the student submitted at least ten of the twelve worksheets, s/he was awarded ten marks. Any less than ten worksheets and the student received no marks for this component of the assessment. The drawback of the Book in Moodle is that it is not possible to provide an element of interactivity.

To improve the experience, interactivity was introduced to the online content in 2016. During the previous year, it was noted that some students were not logging on to Moodle to work through each week’s book. Instead, they were copying from their colleagues immediately prior to their laboratory class. To encourage students to at least look at the content, all Books were converted to Lessons in 2016. Lessons offer interactivity because it is possible to embed a variety of types of questions (true/false, multiple choice, matching, short answer, etc.). It is also possible to provide immediate feedback to students based on their answers. Students had no choice but to log on to Moodle and interact with the content to receive their weekly progress marks because their responses replaced the paper-based worksheets used in 2015. In addition to the embedded questions, an element of gamification was also incorporated into the 2016 online content to improve the online experience. Little penguins, in different costumes each week, were hidden throughout the lesson. Clicking on the penguin gave students access to a bonus question derived from tests and final exams in previous years.

Effect of Blended Learning on Exam Performance

The variation of exam results across years was assessed by analysis of covariance using WAM as a continuous covariate to adjust for year-to-year variation in the student cohort (Minitab 17). In this context WAM is the weighted average mark of all subjects taken in the first and second year of the undergraduate course. Analysis of covariance showed that the slope of exam results versus WAM was constant across years, allowing one to estimate the effect of each year on exam outcomes without the effect of WAM. The effect of online content was assessed by comparing exam results for blended learning (years 4-5) with the historical control group (face-to-face lectures, years 1-3). Class sizes for each year were in the range 81-99 (450 students assessed in total).

Usage Patterns of Online Content

The Moodle course log file was downloaded as a comma separated text file using the menu command: *Course administration→Reports→Logs*. Each record of the log file is an event. The logged events include relevant fields such as the *Time, User full name, Event context, Component,* and *Event name*. The *Component field* is the Moodle activity type (Lesson), while the *Event context* denotes the specific lesson. The *Event name* includes the specific actions a student takes within each lesson. These include *Lesson started, Lesson ended, Question viewed, Course module viewed* and *Course page viewed*. Typically several event logs are recorded once the student enters the lesson. These events are used to estimate the time a student is online for each lesson.

The time field was subdivided into 15 minute sampling intervals. A student was considered to be online and engaged in that activity if they had at least 1 lesson event during each 15 minute sampling interval. Students usually logged several lesson events in each 15 minute sampling interval. The proportion of time spent on each lesson was calculated by dividing the number of events for that activity by the total number of events.

The log file was loaded into MATLAB as a table. The event log table was then parsed into a student record table which included identification fields, block test and exam question results, WAM (Figure 1), and lesson activity data. The lesson activity data included the estimated time they spent online for that lesson, and an time series histogram.

Predictors of Exam Performance

The Moodle log file chronicling student online activity was collated using software written in MATLAB R2015b. The software displays time series data, including the number of log events for each component activity (Lesson) over the course and exam preparation period. The study time for each lesson was estimated from the Moodle data log, which records the time a student changes the pages of each lesson. The effect of online study and WAM on specific exam questions was modelled using linear regression.

The statistical relationship between assessment results and student properties such as WAM and online activity was modelled using linear regression (MATLAB function, *fitlm*). MATLAB code is available from the corresponding author upon request.

Results

Effect of Blended Learning on Exam Outcomes

Student satisfaction (green dots in Figure 2A) did not change following the change in delivery mode. Student WAMs and final exam distributions are illustrated by boxplots in Figure 2A. Analysis of variance showed that WAM and Year were a significant source of variance (p<0.001). There was a very large effect of WAM on exam mark, but still differences among years.

Figure 2B shows the correlation between WAM and exam mark for each year. Linear regression was performed on WAM and exam mark. The relationship between WAM and exam mark was modelled by the equation $y = mx + b_{year}$ where y is exam mark and x is WAM. The gradient of the regression line was similar for each year and close to one $m = 1.12 \pm 0.08$ (standard error, p<0.001). Controlling for the effect of WAM on exam mark (m the same for all years), there was not a significant difference between the years 2012-2014 and 2015-2016 .Therefore we did not detect an effect of blended learning on exam outcomes using historical data.

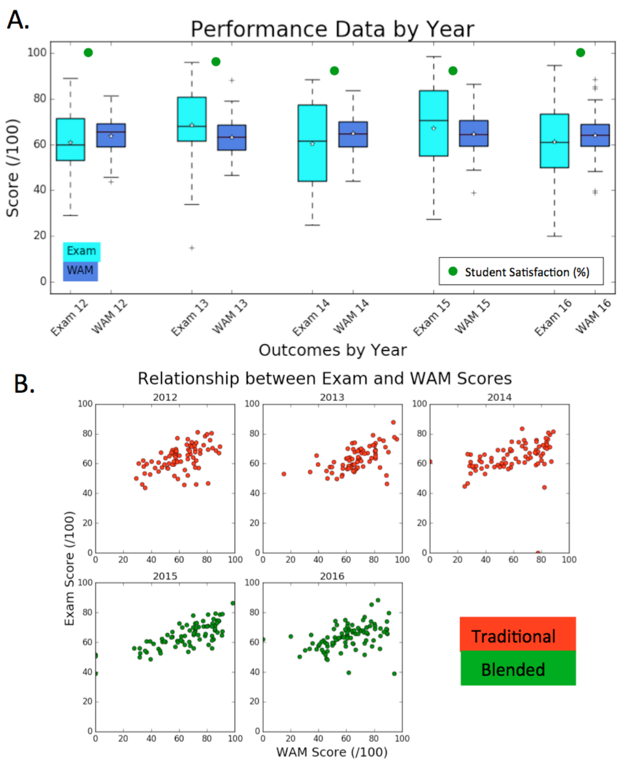


Figure 2. Performance in the course and the degree to date. A: Boxplots showing exam and weighted average mean (WAM) marks by year; and B: Relationship between exam and WAM scores by year

Usage Patterns of Online Content

Logged events were sorted into lessons (see Figure 1C) and plotted as time series histograms where the time of each logged event was binned into 15 minute time intervals (**Error! Reference source not found.**). The scheduled week of each lesson correlates with the onset of activity for that lesson. Block test were held on week 6, 9 and 11. WAM had a significant effect on the block test scores (block test 1: $p<0.001$, block test 2: $p=0.007$, block test 3: $p<0.001$). The duration of online study prior to each block test was only significant for block test 3 ($p<0.001$). The effect of online study and WAM for block test 3 was fitted to a linear model which showed that the effects of online study and WAM were additive. The interaction between WAM and online study was not significant. The adjusted R-squared value for this model was 0.27.

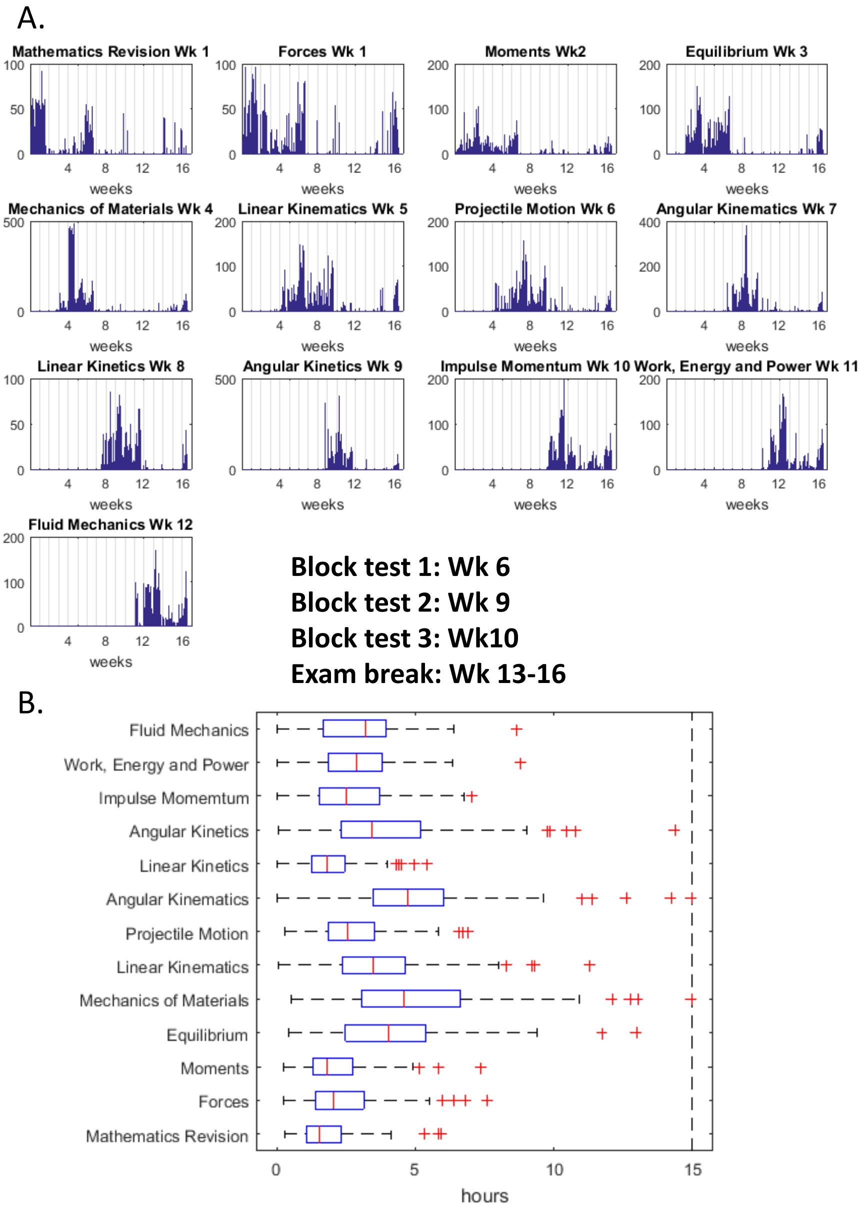


Figure 3. Online activity of students. A: Times series histogram showing student online activity for each lesson in 2016; and B: Boxplots ('Traditional' format, Matlab) showing the student distribution of online study hours for each lesson in 2016. The blue box shows the 25th-75th percentile range. The red line inside the blue box is the median, while outliers (red crosses) are more than 1.5 interquartile ranges away from the box range. Black 'whiskers' denote the 1st and 4th quartiles.

Error! Reference source not found.B shows the distribution of online activity (hours) across the class for each moodle lesson (Figure 1A). The median time that students spent on each lesson is denoted by a red line. The moodle lessons that received the most activity were Angular Kinematics, Mechanics of Materials, and Equilibrium. The red plus signs on the boxplot show statistical outliers who spent in excess of 10 hours on some lessons.

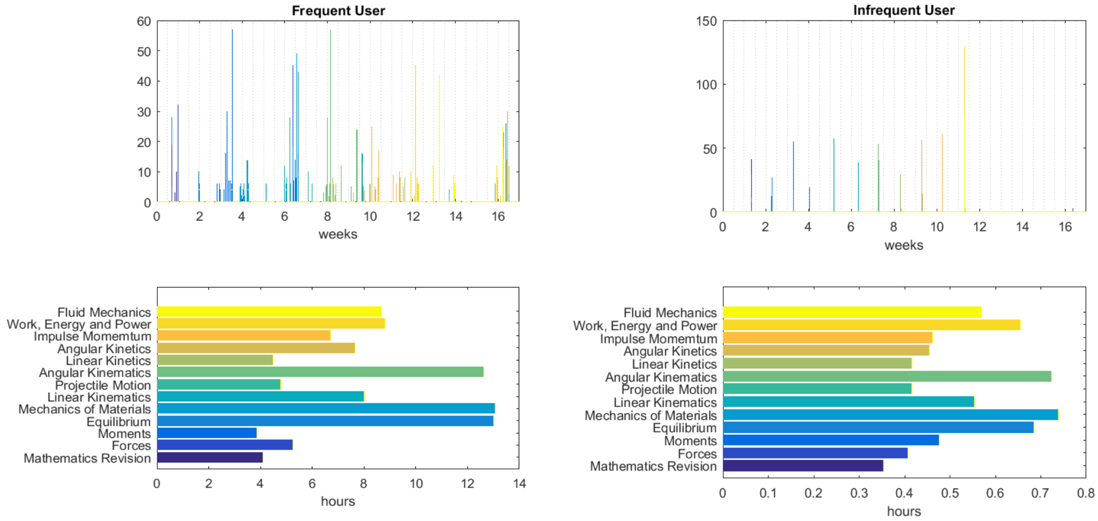


Figure 4. A comparison of student usage patterns (left: frequent user, right: infrequent user). Note that the x-axis scaling differs between users. Lesson were colour coded for time series histograms (upper graphs). They are identical to those shown in the lower horizontal bar graphs which show the estimated time spent on each lesson.

Figure 4 displays usage patterns for two ‘outlier’ students. The left upper time series histogram shows a frequent user while the right upper time series histogram shows the activity of an infrequent user. The horizontal axis of a time series histogram is divided into consecutive 15 minute intervals, while the vertical axis shows the number of log entries for that time interval. The time spent on each activity is calculated by summing the number of 15 minute bins with at least one log (see methods). The lower horizontal bar graphs show the total time spent on each lesson by that student. The frequent user spent over 12 hours on Angular Kinematics, Mechanics of Materials, and Equilibrium lessons, while the infrequent user spent less than 50 minutes on each lesson.

Predictors of Exam Performance

A linear regression model was fitted to the score E for each exam question.

$$E = a_1 + a_2\mathrm{WAM} + a_3\mathrm{WAM}\times\mathrm{Time} + a_4\mathrm{Time}$$

where $a_1 \mathrm{K}\ a_4$ are the estimated coefficients.

The total online study for each student was not correlated with WAM (a_3 not significant, $r^2 = 0.17,\ p = 0.09$**Error! Reference source not found.**). Student performance for each exam question is shown as a box plot in Figure 5A. The class had high scores for static equilibrium questions, and relatively low scores for impulse momentum, angular kinetics and the mechanics of materials. The coefficients a_2 (effect of WAM) and a_4 (effect of online time) are shown in Figure 5B. In general, the interaction term $\mathrm{WAM}\times\mathrm{Time}$ was modest (or not significant) in comparison to the main effects of online time and WAM. The total online study time was significant for some of the harder questions with lower marks (E4 - angular kinetics, p=0.007, and E3 - mechanics of materials, p=0.002). The effect of WAM was significant for all questions except E2 (static equilibrium) and E5 (projectile motion).

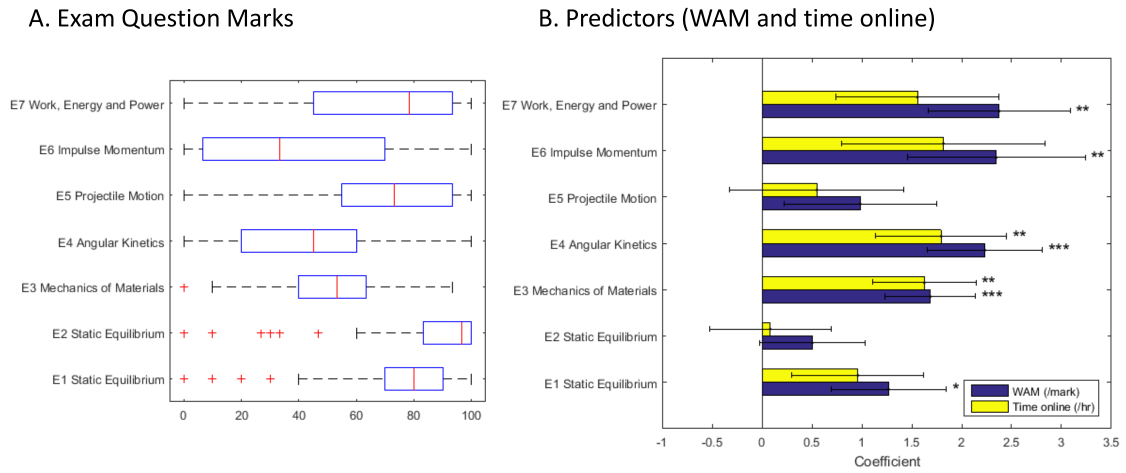


Figure 5. A. Boxplot showing exam question marks distribution B. WAM and time online are independent predictors of exam question marks. (*0.01 < p < 0.05, ** 0.001 < p < 0.01, ***p < 0.001)

Conclusions

WAM was a strong predictor of exam marks. Controlling for the effect of WAM, we did not detect any change in exam marks following introduction of a blended learning model. This result is in agreement with randomised trials. The finding that online activity is a significant predictor of exam performance provides a new approach to assessing the effectiveness of blended learning strategies.

The logging of online activity allows one to monitor student study patterns, and then relate these to exam outcomes. Student engagement with online lessons was visualised using a time series histogram showing the number of interactions with the lesson and the integrated time spent on that lesson. We showed that WAM and the duration of online activity were independent predictors of student exam performance. A positive correlation between the time spent online and exam score suggests that the online activity was effective, though this effect may be indirect. Future studies will assess the utility of the online activity monitoring tool in other courses.

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