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Worked Example Videos for Blended Learning in Undergraduate Engineering

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ABSTRACT

Blended learning is becoming increasingly prevalent in engineering education due to its flexibility and enhanced learning outcomes, however it can face challenges in maintaining student engagement and satisfaction. This study investigates the impact of worked example videos (WEVs) as a blended learning approach within undergraduate engineering, addressing a gap in the literature around their impact as a self-directed study tool in large semester-long courses. WEVs were evaluated using a mixed methods approach incorporating viewership data and surveys. Approximately 90% of students used active learning when interacting with the WEVs, with many taking advantage of video controls to tailor and self-pace their learning. Students agreed WEVs improved their content knowledge and perceived this would improve their grades. Thus WEVs are capable of empowering learning and enabling deeper content engagement, making them a highly effective approach for embedding blended learning in the undergraduate engineering context.

Key words: Blended learning, Problem solving, Streaming video

INTRODUCTION

Blended learning, the combination of face-to-face and online instruction (Garrison and Kanuka 2004), is increasingly becoming the new norm in higher education (Partridge, Ponting, and McCay 2011). This trend is being driven by the significant benefits that blended learning offers, including greater educational accessibility and flexibility, improved pedagogical practice, and enhanced learning outcomes (Osguthorpe and Graham 2003, Singh 2003, Graham 2006). However, the move toward blended learning has its challenges, particularly around managing student expectations of time-management, workload and individual responsibility in the learning process (Vaughan 2007). Where students resist these changes, lower student satisfaction has been reported which can lead to instructors being reluctant to employ blended approaches (Vaughan 2007, Felder 2011). Developing blended learning models which are able to address these key concerns while capitalizing upon the benefits of blending is important for increasing uptake and buy-in. This is especially true for undergraduate engineering education which has historically relied upon transmissive lectures as the main mode of delivery. In light of this, this study aims to evaluate the effectiveness of worked example videos (WEVs) as a blended learning approach in math-heavy undergraduate engineering courses.

Blended Learning

The spectrum of how traditional face-to-face classes have been transformed into blended classes is vast (Graham 2006, Clark, Kaw, and Besterfield-Sacre 2016). The first generation of blended learning mostly involved the direct video recording of physical lectures (Singh 2003), a practice which is still commonly used today (Kay 2012, Chester et al. 2011). While this approach does address the benefit of accessibility for students, it does little to improve the educational experience as it simply mimics a passive classroom event. In fact, video lectures have been reported less engaging than face-to-face lectures due to viewing distractions in the home environment (Foertsch et al. 2002). Students may also use lecture recordings as a substitute for attending classes (Wieling and Hofman 2010).

Fortunately, with the reduction in cost and wider availability of technology like recording devices, editing software, and online learning platforms (McGarr 2009, Kay 2012), more advanced blended learning approaches like the flipped classroom, adaptive learning and online modules have emerged (Kakosimos 2015). These practices represent a significant shake-up of the learning and teaching approach, as they move the focus away from teacher-centered experiences to incorporate more student-centered learning activities. For example, in a typical flipped model, lectures are presented online for students to review prior to engaging in activities within the classroom (Bishop and Verleger 2013, Reidsema et al. 2017, Ahn and Bir 2018). Similarly, online modules can be used to prepare students for face-to-face classes, and when integrated with quizzes and self-evaluations, the results can be leveraged by the instructor to adapt the face-to-face activities to the skill levels and interests of the students (Kakosimos 2015). In engineering, simulations and remote laboratories have also been used to create blended experiences (Michau, Gentil, and Barrault 2001). Here the online and face-to-face components are developed such that they complement each other, thus capitalizing on the benefits of blending.

A key aspect of these more innovative blends is the concept of active learning. This is defined by Prince (2004) as activities where students "do meaningful learning activities and think about what they are doing." Examples of active learning techniques include group discussion, individual practice, group-based problem-solving and teaching others. This is contrasted against transmissive modes of teaching where the instructor projects information that students passively engage with, usually by listening or copying down (Prince 2004). Active learning has been shown to be a strong factor in increasing student performance in the science, engineering and mathematics fields (Vos and de Graaff 2004, Freeman et al. 2014). In a meta-analysis by Freeman et al. (2014) it was found that in classes designed around active learning students were 1.5 times less likely to fail compared to those in classes with traditional lecturing.

Unfortunately, the more intensive blended learning approaches tend to encounter more challenges in their implementation (Felder 2011). In particular, employing active learning strategies can be met with strong student resistance. This is because the approaches necessitate students take responsibility for their learning, which can be difficult for those accustomed to passive classrooms (Vaughan 2007, Felder 2011). Furthermore, the time, persistence and skill level required to overhaul a course to incorporate active learning has been cited as a major barrier for instructors (Vaughan 2007). Thus, blended models that are less demanding on instructors and incorporate active learning without pushing students so far out of their comfort zone that they disengage are desirable.

Worked Example Videos (WEVs)

Worked example style videos show promise for blended learning in the engineering context. In these, mathematical-based problems are worked through step-by-step while the instructor narrates the process (Kay and Kletskin 2012). WEVs gained significant recognition through the rise of "Khan Academy" (Khan 2016) which has become a major educational resource over the past decade by producing WEVs on a range of topics including mathematics, science, engineering, programming and economics. Further, start-ups have begun targeting this space with companies such as 'SpoonFeedMe' emerging as providers of video summaries for specific university courses (SpoonFeedMe 2017). A major advantage of this type of video resource is that it can be made once and then reused, making them highly scalable and efficient. WEVs also tend to have low production requirements, meaning they can be generated quickly with few resources.

One opportunity for capitalizing on the popularity of WEVs within undergraduate engineering is by enhancing how students engage with content outside of class. According to the theory of self-regulated learning, students regulate their learning by continuously evaluating the quality of their learning products (Mirriahi et al. 2018). In the context of self-directed study in math-heavy engineering courses, students are often given homework exercises with written solutions to assist this process.

This enables students to compare their solutions to the model ones, and reason with themselves on whether they have grasped the concepts (Belski 2011). However, a major influence on the quality of this metacognitive monitoring is prior knowledge (Mirriahi et al. 2018). As written solutions are unable to effectively convey the underlying problem-solving strategies and thought processes used to develop a solution, students must infer from the lines of working why the process has been done a certain way. If students lack the necessary prior knowledge to reason this correctly, they will tend to solve related problems with ineffective and erroneous techniques (Clement, Lochhead, and Monk 1981). WEVs can overcome this through the instructor's narration, which can justify the process being used and address common misconceptions, providing students with an additional layer of information with which to evaluate the quality of their learning. This is supported by Wandel (2009) and Wandel (2010) who produced WEVs targeted at of thermodynamics students studying in distance mode to understand if the video format was preferred over static written solutions. They found students liked the fuller explanations that the videos offered.

Preference for videos over written formats is also supported by cognitive load research, which indicates that learning is most effective when both visual and audio cues are presented (Whatley and Ahmad 2007, Mayer and Moreno 2003). This is because humans process multimedia information using two channels, visual and verbal, which both have a limited capacity. More can be processed when the information stream is split effectively between the two channels (Mayer and Moreno 2003). The ability to pause and rewind in videos can also assist in the processing of information. Pausing enables students to attempt problems on their own at their own pace and even consult other sources of information to reinforce their learning as they progress through a video. Rewinding allows students to watch a challenging section more than once, giving multiple opportunities to understand the information delivered. This personal agency has been reported as an aspect of video recordings that students enjoy (Kay 2012, Zhang et al. 2006, Chester et al. 2011).

These observations position WEVs as an effective tool for bridging the understanding gap that can emerge as students unpack concepts learned in the classroom for unfamiliar problems in their self-directed studies. This ties into the model of learning presented by Hattie and Donoghue (2016) where students move through surface, deep and transfer phases. Engaging with WEVs as a learning strategy enables the shift from memorizing and reproducing ideas (surface learning) to demonstrating understanding and creating meaning (deep learning). WEVs can also support the transfer of knowledge to new problems and contexts. This is supported by Belski and Belski (2013) who studied knowledge transfer improvements offered by WEVs in an electronics engineering course, finding that the videos contributed to students applying skills to new problems with added complexity. A similar study by Belski (2011) reported that students using WEVs scored higher on exams, while Pinder-Grover, Green, and Millunchick (2011) found it was the students with the least prior exposure to topics who showed the greatest performance benefits from using homework solution videos in a materials and manufacturing engineering course.

There has only been limited research into WEVs in higher education settings, and in particular undergraduate engineering. Areas which have been studied include usage patterns (Belski 2011), student-video interaction (Martin 2016), motivations for engagement (He, Swenson, and Lents 2012) including the types of user-groups present (Lust, Elen, and Clarebout 2013), and influence on academic performance (Belski 2011, Pinder-Grover, Green, and Millunchick 2011). However, these studies tend to suffer from small sample sizes typically less than 100 students (Wandel 2009, 2010, Belski 2011, He, Swenson, and Lents 2012, Belski and Belski 2013, Martin 2016) and in some cases only involve short-term interventions (Crippen and Earl 2004, Kay and Kletskin 2012). The WEVs have also been developed for different purposes such as assisting distance students (Wandel 2009), recording examples covered in face-to-face tutorial classes (Martin 2016), to assist with attempting assessment tasks (Crippen and Earl 2004), and as a way of providing feedback on quizzes and homework (Green, Pinder–Grover, and Millunchick 2012), rather than as a tool specifically for improving the quality of self-directed study. No studies have looked at the impact of WEVs as a blended learning approach for supporting self-directed study in large undergraduate engineering courses, and there is limited understanding of how WEVs can develop mathematical problem-solving skills in engineering. Thus, the present study aims to address these gaps by investigating the impact of WEVs as a semester-long blended approach in large undergraduate engineering cohorts, encompassing a total of 3290 students. The areas of student engagement, usage, attitudes toward the videos, student satisfaction, and the impact on perceived academic performance were investigated over multiple iterations of three courses.

RESEARCH DESIGN

The study was conducted across two and a half years and involved three undergraduate engineering courses at the Queensland University of Technology, a large public university based in metropolitan Brisbane. Numerous WEVs were created for each course, specifically aligned to the content delivered throughout the semester. The videos were promoted as a resource for students to use in their self-directed study after engaging in face-to-face classes. The impact of the videos was evaluated with a mixed methods approach incorporating usage analytics and surveying.

Courses and Student Participants

The courses chosen for this study were Mechanics (MEC), Dynamics (DYN) and Control Systems (CON). Mechanics (also known as statics) was a first-year core course taken by all engineering students concerned with the physical behavior of structures subjected to forces. Students are not expected to have selected a major at the time of taking this course. Dynamics was a second-year course taken by students in the mechanical engineering stream which introduced the concepts of dynamics for particles and rigid bodies. Control systems was taken by mechanical engineering students in their third or fourth year, and focused on modelling systems using transfer functions and then using these to design simple feedback controllers. These courses were selected for this project given they introduce and then build upon challenging yet fundamental engineering concepts (Steif and Dollar 2005), have historically poor progression rates (Prusty et al. 2011), and have significant emphasis on mathematical-based problem-solving which makes them well-suited to the WEV concept.

Each course was run on-campus over a semester (13 teaching weeks), with contact hours, assessment and year level listed in Table 1. Attendance was not enforced and lectures were recorded and made available online. Problem-solving tasks, quizzes and final exams directly assessed problem-solving skills with mathematical-based questions. It is worth acknowledging that assessment practices in Australia differ from North America – in Australia it is common to have a highly weighted final exam compared to in the United States where a greater focus is given to weekly homework tasks. Efforts were made to keep the courses consistent with lecture and tutorial notes only tweaked between semesters, while assignment and exam questions were designed to have the same structure, length, topic coverage and difficulty. Each course's coordinator stayed with the course for the duration of the study, however there was some turnover of staff in the teaching teams due to the nature of employing teaching assistants on a casual basis. Dynamics was the first course to incorporate the WEVs in Semester 1, 2016 with WEVs incorporated into Mechanics from

Table 1. Course attributes.

Attribute	Mechanics	Dynamics	Control Systems
Year Level Taken	First-Year	Second-Year	Third or Fourth-Year
Contact Hours			
Lecture	2 hours/week	3 hours/week	2.5 hours/week
Tutorial	1.5 hours/week	1.5 hours/week	1.5 hours/week
Lab	2 x 2 hours	5 x 2 hours	2 hours/week
Assessment Items (Weighting)	3 x Online Quizzes (20%) Group Design Project (30%) Final Exam (50%)	Problem-Solving Task (25%) Computer Lab Task (25%) Final Exam (50%)	2 x Problem-Solving Tasks (50%) Final Exam (50%)
Cohorts	MEC1: Semester 2, 2016 MEC2: Semester 1, 2017 MEC3: Semester 2, 2017 MEC4: Semester 1, 2018	DYN1: Semester 1, 2016 DYN2: Semester 2, 2016 DYN3: Semester 1, 2017 DYN4: Semester 2, 2017 DYN5: Semester 1, 2018	CON1: Semester 1, 2017 CON2: Semester 1, 2018

Semester 2, 2016 and then Control Systems in Semester 1, 2017. Data has subsequently been collected for five cohorts of Dynamics, four cohorts of Mechanics and two cohorts of Control Systems (noting this course only runs once per year).

Demographic characteristics by semester cohorts are included in Table 2 below. Overall, semester cohorts averaged 17% female students, 81% Australian domestic students and 51% school-leavers (defined as students who enroll in university directly after high school). The university entry score in Queensland is known as an "Overall Position" (OP) and varies between 1 (the highest) and 25 (the lowest). It can be seen that the OP score is highly consistent among the semester cohorts, averaging 7 overall.

Production of WEVs

Videos were produced using a Microsoft Surface Pro 4 computer, including the pen accessory. Microsoft OneNote was used as a blank page to capture writing on the screen. The first set of videos made for Dynamics used Microsoft Screen Expression for screen and audio recording. This program was subsequently replaced by Screencast-O-Matic as it was found to be more reliable. The screen capture area was cropped to only include the writing area of the Microsoft OneNote page, and not the ribbon or taskbar. Due to time limitations of the recording programs, Microsoft Movie Maker was used to edit together segments of the capture when required. Further editing was only completed to cut out major mistakes as part of the strategy to make the videos appear more natural to the viewer (discussed below). For some Control Systems videos, the use of Matlab software was demonstrated to compare manual and simulated solutions. Figure 1 shows screenshots of WEVs and an example of a typical video can be found here: https://youtu.be/PG53Bbwb2h8. The videos were uploaded unlisted to a YouTube channel and then embedded within the learning management system (LMS) of Blackboard. The same instructor produced the videos for each course in this study. They worked as a teaching assistant facilitating up to three tutorials for three of the four Mechanics cohorts and two of the five Dynamics cohorts. The instructor was not a teaching assistant for the Control Systems cohorts.

Design of WEVs

The WEVs were developed such that each one focused on a single mathematics-based engineering problem. At the start of each video, the question was introduced by the instructor. The problem-solving approach to be employed was then broadly discussed, before the instructor worked through the example systematically step-by-step by writing on the screen. Audio was used to narrate the process and as recommended by Clark and Mayer (2008), emphasize connections between steps and the underlying principles. Common mistakes and misconceptions were also clarified through this process. Diagrams and visuals were used where appropriate to better communicate key concepts (Mayer 2001).

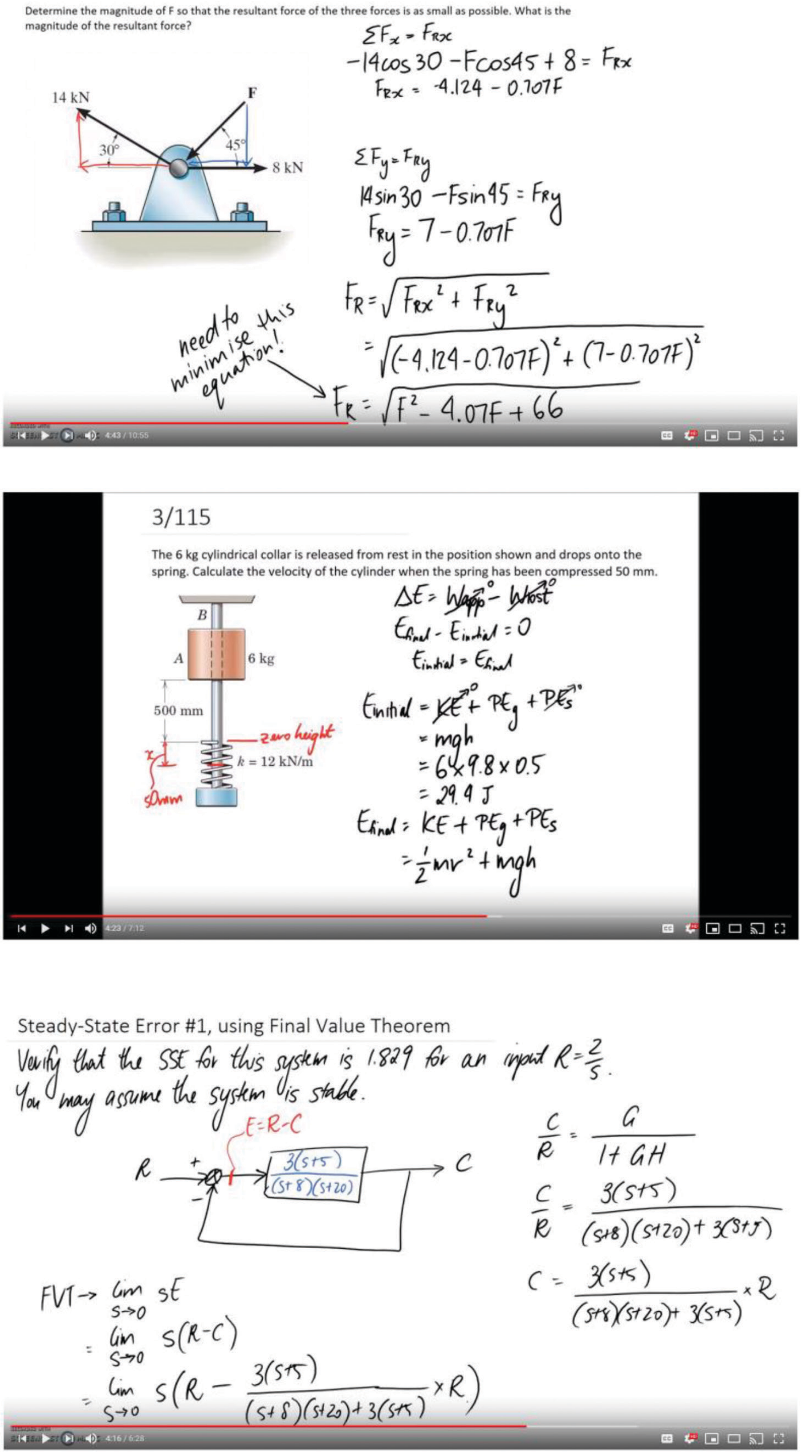

Figure 1. Screenshots of worked example videos from Mechanics, Dynamics and Control Systems.

The WEVs were designed to break down the barrier between the instructor and the viewer, to maximize engagement and thus encourage active learning. In line with this, the WEVs incorporated a conversational communication-style, with tone and language representative of a tutorial. This is supported by Mayer (2001) who advocates that a conversational approach is better for learning than a formal one, as viewers tend to feel that the instructor is engaging with them personally. To further enhance this, video editing was used sparingly, so the real-time thought process of the instructor was captured, maintaining the feel of a natural tutorial.

The WEVs were aligned with the key content covered in face-to-face classes, but covered example problems which were different to those in lectures and tutorials. Typically three to four WEVs were produced for each weekly topic, ranging in difficulty from simple to challenging. The WEVs were complemented by a 'recap' video for each topic which was similar to the summary presented at the beginning of tutorials. These summaries are also promoted in the literature as a useful tool for reviewing lecture material and for exam preparation (Whatley and Ahmad 2007, Green, Pinder–Grover, and Millunchick 2012). Videos were typically between five and twenty minutes in length, with an average length of 10 minutes. They were released to students at the end of the relevant week and promoted as a supplementary follow-up and self-directed activity. For the MEC3 and MEC4 cohorts, a set of 20 additional WEVs were created to align with a sample exam and were released at the end of semester for students to use as preparation material.

Data Collection

Viewing statistics for all cohorts were collected from YouTube. This was due to limitations of the LMS which meant only visits to the webpage could be tracked, and not whether students watched the videos. However, it should be noted that as the videos were not publicly listed, all traffic recorded on YouTube can be assumed to stem from students in the relevant courses.

To assess student engagement, interaction and attitude toward the videos, as well as the impact of WEVs on perceived academic performance, an anonymous survey was run at the end of each semester. The survey had 10 to 12 questions across a combination of checkbox, Likert scale and open-ended comment responses. The survey was available online and was estimated to take five minutes to complete. Overall, 19% of students completed the survey with response rates broken down by cohort in Table 2 below, noting that the first dynamics cohort (DYN1) was not surveyed. Students identified across the spectrum for watching videos from all, most, half and few topics, however very few students responded for the null watching category. Domestic versus international students as well as school-leavers (those who enrolled in university directly after high school) versus non-school leavers (those who came to university later) were consistent with the proportions of these groups present at the course level. This suggests the sample of students who completed the survey were representative of the broader population in terms of demographics, but video users were overrepresented. Thematic analysis was applied to student comments describing how they interacted with the WEVs with data coded manually into two major themes of video controls and prompting. Following the qualitative analysis framework used by Braun and Clarke (2006), two researchers looked for patterns amongst the codes. A data driven inductive analysis was used. The analysis focused on interpreting and explaining student comments and resulted in selection of the two major themes described above. The university satisfaction survey was used to compare the student experience before and after WEVs were introduced. This survey was administered by the university midway through and at the end of each semester to evaluate the overall course experience. The Likert scale question "I am satisfied with this course" was used as a measure of student satisfaction for the present study. Response rates on this survey are also included in Table 2.

RESULTS AND DISCUSSION

To understand the impact and effectiveness of WEVs, several areas were analyzed including usage statistics, student interactions with WEVs, student satisfaction, and impact on perceived academic performance.

Usage Statistics

Table 2 presents key metrics across the eleven cohorts, totaling 3290 students. It is immediately apparent that the videos were highly utilized with approximately 55,000 recorded views, and students averaging 58 minutes of total viewing time. The highest engagement rates were observed in the MEC3 and MEC4 cohorts, largely due to the additional sample exam videos which proved extremely popular. In fact, the sample exam WEVs gained more views than the weekly videos for these cohorts. Promotion of the videos did improve in later semesters with the teaching team more regularly communicating the benefits of the videos and encouraging students to use them, however there is not a clear upward trend in usage over time to suggest this had a major impact upon usage rates.

To further investigate viewership, the distribution of views throughout the semester was explored (Figure 2). Here the data has been averaged for each course, and normalized against the number of students. The sample exam views have been excluded to improve comparative power between the courses (noting all sample exam views were in the exam period). As the timing of the final exam has varied within the exam period (Weeks 15 to 17) between cohorts, exam block views have been merged into a single data point for comparison.

Table 2. Key metrics of videos and surveys across cohorts. Note that (SE) shows the portion of the total associated with the sample exam, relevant only to the MEC3 and MEC4 cohorts. Color shading shows relative engagement from red (high) to blue (low).

Attribute	MEC1	MEC2	MEC3	MEC4	DYN1	DYN2	DYN3	DYN4	DYN5	CON1	CON2
Demographic Characteristics of Student Cohorts											
Students	685	399	607	317	277	161	218	183	214	75	154
Female (%)	16	20	16	18	15	18	15	20	22	19	12
Domestic (%)	83	82	87	86	82	71	82	74	83	82	79
School-Leaver (%)	58	44	61	61	49	44	55	43	60	47	43
Average Entry Score	7.1	6.4	7.0	6.7	6.6	6.6	6.8	6.8	6.4	7.1	6.5
Video Totals											
Videos (SE Portion)	55	55	75 (20)	75 (20)	42	44	44	44	44	40	43
Views (SE Portion)	8538	6700	14751 (7597)	7577 (4160)	3396	2453	3393	2152	2719	1183	1649
Hours Viewed (SE Portion)	671	568	959 (362)	502 (198)	361	203	332	229	311	97	168
Video Usage Normalized Per Student											
Views/Student (SE Portion)	12.5	16.8	24.3 (12.5)	23.9 (13.1)	12.3	15.2	15.6	11.8	12.7	15.8	10.7
Minutes/Student (SE Portion)	59	85	95 (36)	95 (37)	78	76	92	75	87	78	66
Survey Response Rates (%)											
WEV Survey	11	23	23	18	N/A	20	22	25	25	17	21
Satisfaction Survey – Midway	22	21	16	17	22	26	22	18	29	25	20
Satisfaction Survey – End	21	26	15	20	31	23	28	21	24	22	25

The most obvious trend in Figure 2 is the large peak observed during exam block, with 65% of all views recorded during this period. Weeks 1 to 14 of semester represent the 13 teaching weeks plus a mid-semester break week. For Mechanics, two notable peaks were observed here which coincided with quizzes held during Weeks 4–5 and 8–9 of semester (a third quiz was held in Weeks 14–15 but this is hidden by end-of-semester study). Similarly for Control Systems, a peak is evident at Week 6 when the first problem-solving task was due, but the second task was due during the exam period and views associated with it are hidden. Dynamics cohorts showed fairly steady viewership throughout the semester, with only a slight increase in viewing when the problem-solving task was due around the middle of the semester. These findings infer assessment is the largest motivator of

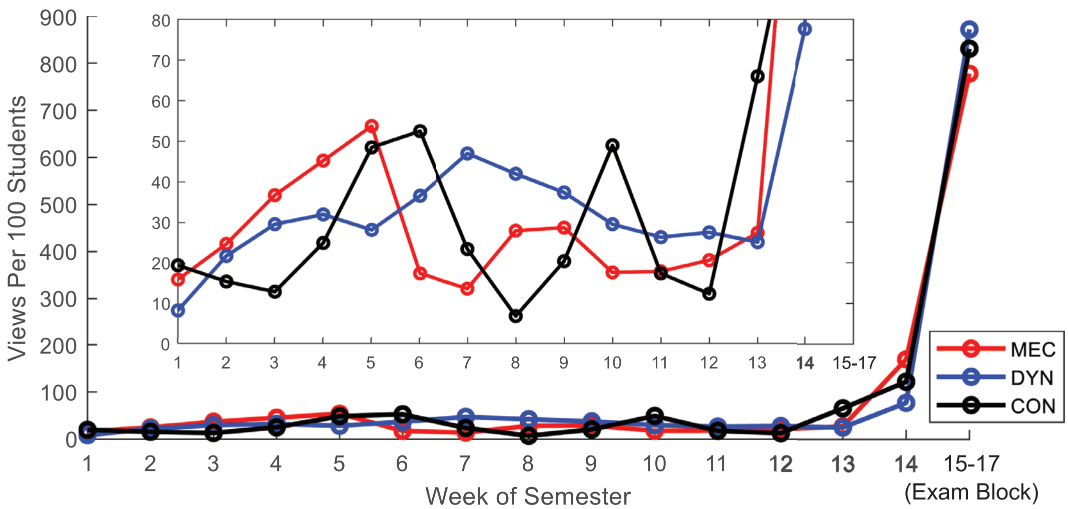

Figure 2. Video views per week from YouTube averaged for each course and normalized against student number (inset zoomed in). Note sample exam views relevant to the MEC3 and MEC4 cohorts have been excluded.

WEV viewership, which is largely unsurprising given that attempting summative assessment tasks tends to be a driver for student learning (Brown 2005) and is consistent with previous higher education video studies (Belski 2011, Lust, Elen, and Clarebout 2013).

Student-Video Interaction

Student interactions with the WEVs were investigated via the end-of-semester survey. Students were asked about their motivations for using the WEVs with results shown in Figure 3 where it can be seen that students in each course show similar trends across the categories. The vast majority of students reported exam revision (the review of course content in preparation for the final exam), as a key driver for using the videos. This is in line with the viewership analysis in Figure 2, as well as student comments which frequently reported WEVs as an excellent tool for systematic revision, such as, “I have looked at the videos as part of my revision … they are a great refresher.” It is interesting that fewer students used the WEVs for assignments, particularly in Mechanics and Dynamics. This may be influenced by the exam having a heavy weighting toward final grade. It may also be explained by the assignments setting a well-defined task which was tested relatively soon after being taught, compared to the exams that assessed general topics taught much earlier in the semester. Significantly more Control Systems students used WEVs for assignments. The key difference here may be there were fewer resources available to support students – this content is less accessible on the

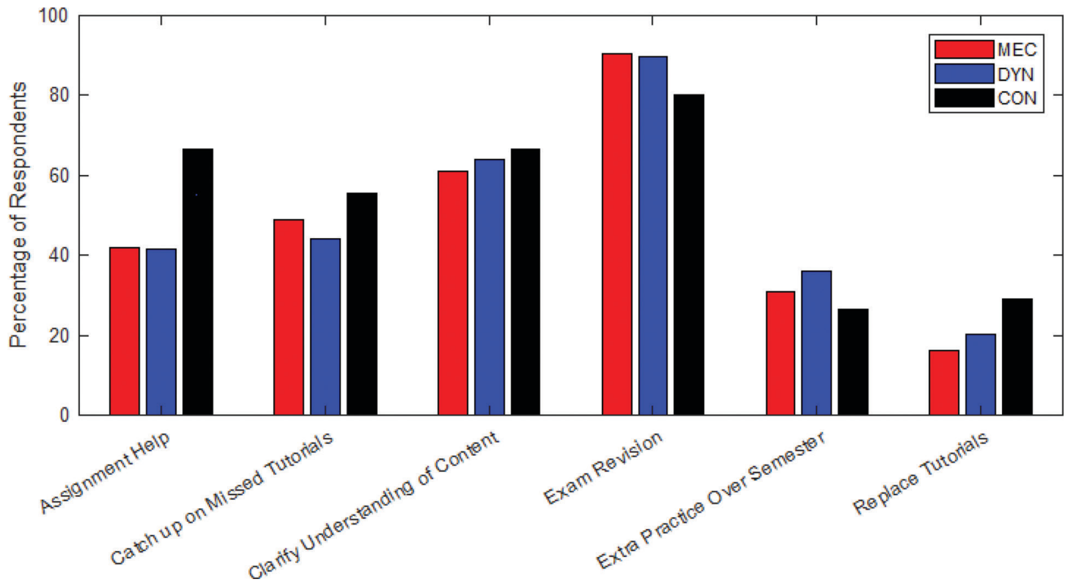

Figure 3. Reasons students reported for using the WEVs from survey responses (only results from 2017 and 2018 reported).

internet and the Control Systems course provided fewer alternative follow-up activities. Thus it is likely that the WEVs were relied upon much more heavily to aid assignment progress that students in the other courses were able to do elsewhere.

The similarity of an assignment's style to the WEVs can also help to pinpoint the types of courses that would see the most engagement with WEV resources. In Mechanics, of the students who reported using the WEVs for assignment help, 98% said this was for quizzes and just 25% for the group project. The quizzes asked students to solve the types of questions presented in the WEVs, while the project required analysis of a structure for its cause of failure and then an open-ended redesign. Likewise, in Dynamics, of the students who reported using the WEVs for assignments, 100% said they used them for the problem-solving task and 64% for the computer lab assignment. The problem-solving task asked questions similar to the WEVs, whereas the computer lab assignment required simulation of problems using software and comparison with hand calculations. This suggests WEVs are well-suited to courses which assess students on solving problems of similar style to those in the WEVs.

Despite assessment being the dominant driver for WEV usage, up to 65% of students reported using WEVs in an ongoing capacity during the semester to clarify understanding of challenging concepts and as additional practice questions. Between 45% and 55% of students reported using the videos to catch up on missed classes, confirming students use the resources for flexibility and accessibility. In Mechanics and Dynamics, 15–20% of students reported replacing tutorial classes with the WEVs compared to about 30% for Control Systems. This suggests that integrating WEVs into first and second-year classes is likely to have only a small impact on face-to-face class attendance, but the impact may be larger for later year courses when students are more likely to have other commitments outside of study and have more mature study skills to cope. This was also noted in a similar study by Chester et al. (2011).

Hypothesizing that WEVs encourage deep and active learning, students were asked about how they typically engaged with the problems in the videos (Figure 4). Reports are fairly consistent across the courses with the "attempt while watching" category being most popular. Approximately 90% of students reported to have solved the examples before, during or after watching the WEV and thus employed an active learning approach (Prince 2004), compared to only 10% of students who did not attempt the examples and consequently used a passive approach. Similar results were reported by Martin (2016) who used WEVs in an electrical engineering course. This provides strong evidence that WEVs can facilitate active learning opportunities where students independently practice their problem-solving skills. This is important as the shift from a receiving learning mode to a participating learning mode is linked to better understanding and knowledge retention (Prince 2004, Freeman et al. 2014).

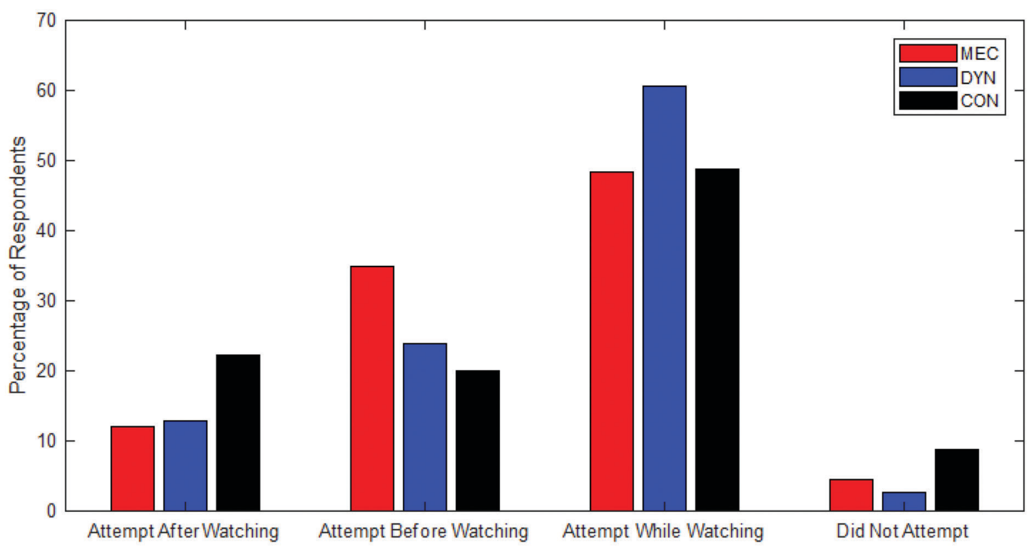

Figure 4. Student responses to how they typically interacted with WEVs (only results from 2017 and 2018 reported).

To further explore student-video interaction, thematic analysis was conducted on open responses where students described how they interacted with the WEVs. The first major theme identified was students using the video controls of pausing, rewinding and skipping. Students frequently discussed using pausing to work alongside the WEVs with comments such as, "I paused throughout the video and attempted to move farther from there and if I was stuck I would continue with the video" and "[I] would most often pause at the moment a point of confusion was cleared up, and work through the rest of the example on my own." This is consistent with the earlier finding that the majority of students were attempting the questions while engaging with the WEVs. Skipping and rewinding were regularly noted as a way of focusing on the parts of a question which were most challenging. This was supported by comments like, "I usually skipped over easy parts and repeated watching the most important parts of solving the question." This suggests WEVs can enable students to individualize their learning and review aspects they find challenging at their own pace.

The second major theme identified in the thematic analysis was prompting, with students using the WEVs to further their learning in different ways. Some students reported using the WEVs to prompt their solution processes in real-time to give hints on how to proceed when they became stuck. This became part of their self-regulated learning cycle, evident in comments like, "I would watch and then pause at certain parts to replicate the methods used when I got stuck. I would then review where I went wrong and continue with the video." This is contrasted against others using the WEVs as reinforcement for their problem-solving strategy such as, "Attempted sections at a time. So when a new part of the solution was about to start I would attempt it and then verify that I did it right with the video." Some students reported using the WEV examples as a guide for attempting additional problems from other sources, evidenced by comments like, "Watched the video and applied the theory to another question" and "Watched example videos and then tried to apply what they showed to solve revision questions." This is consistent with Hattie and Donoghue (2016)'s model of learning where learning strategies can vary between students, and their effectiveness can change as students move through the surface, deep and transfer phases. Thus these results imply that WEVs can serve as a launching pad for further study, leading to deeper learning, critical thinking and knowledge transfer (Hattie and Donoghue 2016). This behavior could be further encouraged by recommending additional practice problems related to each worked example, which was in fact proposed by some students when asked how the WEV concept could be improved. These findings support WEVs as a means of encouraging active learning.

Finally, it is important to note that in the open comment responses, students did not make a distinction in how they used the videos based on their motivation for use (such as exam revision or replacing tutorials). Thus although video usage rates throughout the semester were strongly correlated to the assessment schedule, the use of the active learning strategies when interacting with the videos was universal.

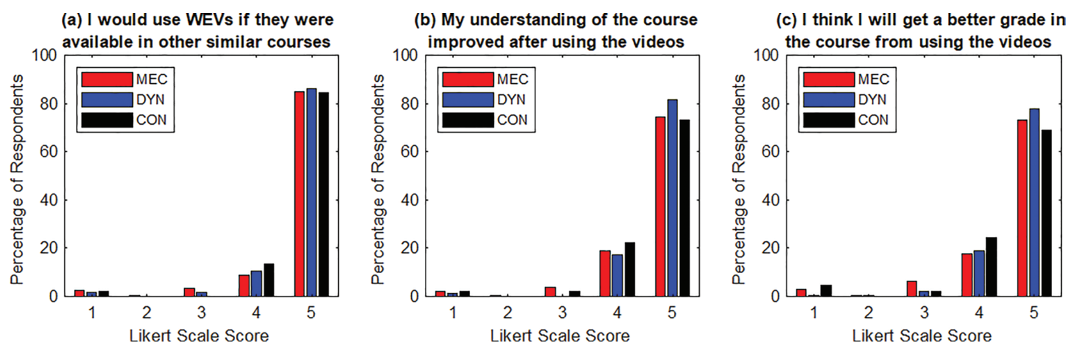

Figure 5. Likert scale responses (1 = strongly disagree, 5 = strongly agree).

Student Satisfaction

The impact of videos on student satisfaction was assessed through both the end-of-semester survey and the course satisfaction survey administered by the university. On the end-of-semester survey, students were asked if they would use videos if they were provided in other similar courses (Figure 5a). Here it can be seen that the student response is overwhelmingly in favor, with an average Likert score of 4.8. This was also echoed frequently in the open responses, again strengthening the argument that these WEVs would be suitable for other courses.

The university's course satisfaction survey was administered in the same way for cohorts who had access to the videos and those in previous semesters who did not. Satisfaction was measured using the Likert scale response to the question "I am satisfied with this course" (Figure 6). Figure 6 shows satisfaction increased substantially for Mechanics and Dynamics cohorts when the videos were introduced which has been maintained over time. Control Systems showed only a slight improvement from previous semesters, however it should be emphasized that the course was already scoring quite well before videos were implemented, leaving less room for improvement. It must be acknowledged that as with all studies of this nature, there were variables which could not be controlled which impact the strength of this comparison. However on the whole, teaching staff, course structures, student cohorts and assessment strategies in these courses were consistent across semesters, suggesting that the major change of introducing videos was responsible for this increase in student satisfaction. This shows that WEVs have the potential to increase student satisfaction, mitigating one of the key barriers for instructors incorporating blended learning that it risks decreasing student evaluation scores (Vaughan 2007, Felder 2011).

Impact on Perceived Academic Performance

The end-of-semester survey also assessed whether students felt their understanding of engineering concepts had improved and if they would get a better grade from using the WEVs. The results are shown in Figure 5(b–c). This shows most students strongly agree the WEVs had a positive impact on

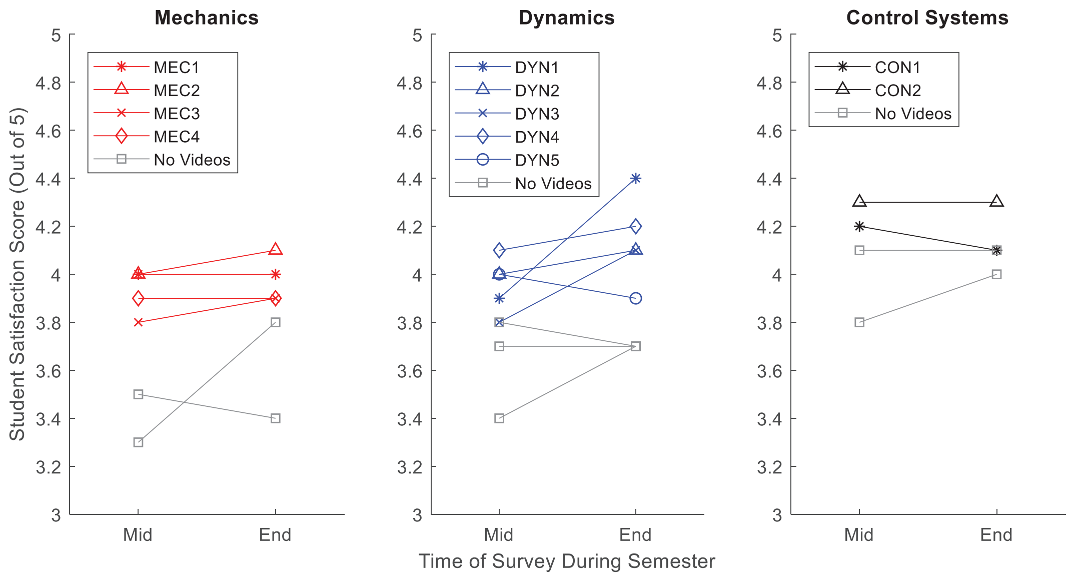

Figure 6. Likert scale responses to "I am satisfied with this course" for cohorts before and after videos as reported on the university satisfaction survey (1 = strongly disagree, 5 = strongly agree); previous cohorts without access to WEVs are shown in grey.

their technical content knowledge, and they perceive this would result in better grades in the course. This suggests WEVs can contribute to improving academic performance. Furthermore, students agreeing that their understanding had increased, suggests that they were not using the WEVs as a tool for memorizing solution processes, but rather learning the content on a deeper level (Hattie and Donoghue 2016). This was supported by student comments such as, "It really helps to see and hear why a problem is solved in a certain way, sometimes just looking at solutions doesn't explain why/how they got to that solution" and "[I watched] the videos to get a thorough and elaborate understanding on each topic." Further investigation is required to understand whether the perception of academic improvement and enhanced understanding is observed in reality, and whether this differs for the various user types (eg. non-users, selective users, intensive users (Lust, Elen, and Clarebout 2013)).

Discussion of Instructor Barriers

One of the key barriers cited by instructors for incorporating blended learning techniques into traditional classes is the time and skill required (Vaughan 2007). However, in this study WEVs were able to be produced quickly given that the instructor's pen strokes and voice were recorded in real-time with no significant editing completed. As an indication of the time required, a 10 minute video was estimated to take approximately 30 minutes to produce when including time to choose or develop the example, pre-work it, record the video, upload to YouTube and embed into the LMS. As the content and style of the videos matched lectures and tutorials, the only major skill development required was familiarization with the recording environment and process for uploading the videos. These observations show WEVs do not place a large burden on instructors compared to other blended learning approaches such as a flipped classroom which is often associated with more sophisticated video resources and a major change in physical delivery style. Similarly, adaptive learning typically requires significant effort in content development and mapping, while online laboratories require investment in software and infrastructure (Michau, Gentil, and Barrault 2001).

The videos in this study were produced weekly during the semester they were first introduced into each course, with the exception of two videos for Dynamics and three videos for Control Systems. These were added from the second semester to further address challenging concepts identified in the initial implementation. The videos were then rolled out to subsequent cohorts in an identical form with no additional effort required. This was enabled by the courses having consistent content, and by selecting examples which were relevant to the overall topics. This makes the WEV concept extremely efficient for large cohorts and for courses which run regularly, as the videos only need to be made once but can then cater to each additional student at no extra cost. This economy of scale also applies at the student consultation level, as the videos were answering student questions which would otherwise have required one-to-one appointments. This was evidenced in student comments such as, "these videos clear many of the weekly questions I have about that week's topic. Watching them saves me emailing my tutor [teaching assistant] and clogging up their inbox, or worse waiting until the next week to ask [in person]." Thus although there is an initial outlay of time and effort required to generate the videos, much can be gained back in other areas and as the videos are released to subsequent cohorts.

CONCLUSIONS

This study investigated WEVs as a blended learning approach in three math-heavy undergraduate engineering courses. It was shown that WEVs are well-suited to this type of course, underscored by the significant viewership, increase in student satisfaction, and positive student attitudes observed in this study. The most dominant driver of WEV usage was exam revision, with clarification of concepts, additional practice, catching up on missed classes and assignment help being secondary motivators. Only a small number of students reported using the WEVs to replace tutorials, indicating that the WEVs were primarily used to compliment face-to-face classes.

Approximately 90% of students use an active learning approach when interacting with the WEVs, taking advantage of the pausing, skipping and rewinding functionality to tailor and self-pace their learning. Students described working alongside the WEVs to provide hints and verify solution processes, as well as concentrate on challenging sections. The overwhelming majority of students agreed WEVs improved their content knowledge, perceived that this would improve their grades, and that WEVs would be useful in other similar courses. In conclusion, this study has shown that WEVs are a popular resource amongst students, capable of empowering learning and enabling deeper engagement in undergraduate engineering. As such WEVs can be an effective tool for embedding a blended learning approach within undergraduate engineering courses.

Extending upon this investigation, an interesting area for future work would be looking at whether students' perception of improved understanding is actually observable. Taking this further, it would be interesting to unpack how different types of students benefit from the WEVs – for example high achievers versus low achievers, international students versus domestic students, and students who binge watch versus those who engage regularly over the semester. Another interesting area to explore would be how WEVs are perceived in other pedagogical and educational contexts, thus going beyond blended learning in an Australian framework. For example, it is likely that those studying via distance would benefit from WEVs, while with different cultural norms around class attendance and assessment practices, it may be found that WEV usage patterns diverge from the large the end-of-semester spike observed in this study. Finally, given the potential applicability of WEVs beyond engineering, there is scope to compare their impact in other fields like business and science.

ETHICS APPROVAL

This research was approved by QUT's Human Research Ethics Committee (approval number 1600000165).

DISCLOSURE STATEMENT

The authors have no conflicts of interest to disclose.

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