Worked Example Videos as a Valuable Blending Learning Resource in Undergraduate Engineering Units

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SESSION C1: Integration of theory and practice in the learning and teaching process

CONTEXT Within many maths-heavy (MH) undergraduate engineering units (UEU), teaching teams rely on written worked-solution documents to assist students in bridging the gap between tutorials and self-directed study. However, these are limited in their usefulness as they are a passive medium and poor at communicating the 'why' required for deeper understanding. Alternatively, worked-example videos (WEVs) involve an instructor demonstrating a solution while discussing the underlying strategies being employed. The audio-visual medium encourages increased interaction with the content, promoting cognitive processing and improving the quality of student learning. Limited studies have investigated the potential for WEVs as high-quality blended learning resources in UEU. Better understanding of WEV impact could lead to their widespread use in the blended learning transformation.

PURPOSE To explore the impact of WEVs in MH-UEU by investigating student-video usage, interaction, and attitude, and the resultant effect on perceived academic performance.

APPROACH WEVs were produced weekly for two MH-UEU at the Queensland University of Technology. Student engagement, perceived academic performance and attitude toward the WEVs were evaluated using a mixed methods approach incorporating viewership data and an end-of-semester survey. The study comprised 1,713 students across five cohorts over three semesters.

RESULTS Students engaged significantly with the WEVs with almost 24,500 views and 89 days of continuous viewing time across the five cohorts. Exam preparation was the dominant motivator for WEV usage. Approximately 90% of students used an active learning style when interacting with the WEVs, with many taking advantage of video controls like pausing, skipping and rewinding. This enabled students to work alongside the WEVs, using them to provide hints and verify solution processes, as well as concentrate on specific sections of the WEVs, thus individualising their learning to focus on areas they found challenging. The majority of students agreed WEVs improved their knowledge of the unit content, had the potential to improve their grades, and would be useful in other similar units.

CONCLUSIONS WEVs are a valuable blended learning tool, capable of empowering student learning and enabling deeper engagement with problem solving tasks. Student interactions with the WEVs suggest that they are well-suited to MH-UEU where worked examples are an important learning tool.

KEYWORDS Worked example videos, blended learning, supplementary videos

Introduction

Engaging students in curriculum is a perpetual challenge, which is now being confronted by the move away from traditional lecture and tutorial delivery into the online space (Whatley & Ahmad, 2007). Blended learning, the combination of face-to-face and online instruction (Garrison & Kanuka, 2004), is the new expectation for engineering education. One opportunity of blended learning is the introduction of worked-example videos (WEVs) to complement the traditional written worked-solutions provided in maths-heavy undergraduate engineering units (MH-UEU). Considerations must be made for how online resources impact on the student experience and learning outcomes. Yet, there has been limited study into the integration of WEVs in UEU. This study will investigate the impact of introducing WEVs into two semester-long UEU. Their impact in terms of student engagement, attitude and achievement, will be evaluated to understand whether WEVs are a suitable blended learning resource for integration into existing units.

Background

Videos are a popular method for delivering online experiences (McGarr, 2009). The rise in their use has been enabled by the advent of YouTube and the accessibility of recording devices like smart phones and tablets, which has made videos cheap and easy to produce (Kay, 2012). Based on a comprehensive literature review by Kay (2012), most videos in the tertiary context have been recorded lectures and audio-overlaid PowerPoint presentations. These video types do not represent innovative approaches to developing online resources, as each mimics a passive classroom experience with little potential for encouraging active learning like group discussion, practice or teaching others (Prince, 2004). This approach to blended learning is counterproductive as video lectures have been shown to be less engaging than face-to-face lectures (Foertsch, Moses, Strikwerda, & Litzkow, 2002) and can serve as direct replacements for classroom experiences leading to reduced class attendance (Wieling & Hofman, 2010). Despite this, there is benefit in the convenience that these videos provide students in terms of ease of viewing and flexibility, as well as for instructors for ease of production and inclusion into existing courses (Wieling & Hofman, 2010).

Another type of video resource is the worked-example style, where mathematical-based problems are worked through step-by-step while the instructor narrates the process (Kay & 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 short WEVs on a wide range of topics. However the study of their impact in the tertiary education context has been limited (Kay, 2012). With regard to undergraduate engineering, Wandel (2009) and Wandel (2010) produced WEVs targeted at external students of thermodynamics. Belski (2011) and Belski and Belski (2013) studied the effectives of traditional written solutions compared to WEVs, as well as knowledge transfer improvements for an electronics unit. Martin (2016) used videos to demonstrate examples in an electrical engineering unit, however only a handful were made available which were not completed in class. Student cohorts were less than 100 in each of these studies. Thus there is a gap in evaluating the impact and value of WEVs in blended learning for large units.

WEVs show promise for blended learning because they can meet students at their point-of-need when practicing during their self-directed studies outside of class, making them an excellent resource for complementing face-to-face instruction. In fact, start-ups have begun targeting this space with companies such as 'SpoonFeedMe' emerging as providers of video summaries for specific university courses (SpoonFeedMe, 2017). Video explanations are superior to the written solutions traditionally provided for self-directed practice, as written solutions are unable to effectively convey the underlying problem solving strategies and thought processes used to develop a solution. Instead, students must infer from the lines of working why the process has been done a certain way, with students who are unable to reason this tending to solve related problems with ineffective and erroneous techniques

(Clement, Lochhead, & Monk, 1981). Unsurprisingly, research indicates that learning requires both visual and audio cues to best promote cognitive processing (Whatley & Ahmad, 2007). WEVs can take advantage of this as well as address the major issues associated with other video types. Incorporating WEVs into self-directed study encourages active learning whilst providing a different experience to that in the classroom, making it a genuine blended learning approach.

Methodology

To investigate WEV impact, a study was conducted across three semesters involving two UEU at the Queensland University of Technology; these units were Dynamics (Dyn) and Mechanics (Mec). Dynamics is a second-year course taken by students in the mechanical engineering stream which introduces the concepts of dynamics for particles and rigid bodies, while Mechanics is a first-year course taken by all engineering students concerned with the physical behaviour of structures subjected to forces. Both units focus on mathematical-based problem solving. All students were based on-campus with the face-to-face contact hours listed in Table 1. Attendance was not enforced and lectures were recorded and made available online. The assessment items for each unit are shown in Table 1, where it is noted that the problem solving task, quizzes and final exam directly assessed problem solving skills with short mathematical-based questions. Dynamics was the first unit to incorporate the WEVs in Semester 1, 2016 with WEVs incorporated into Mechanics the following semester. Data has subsequently been collected for three cohorts of Dynamics and two cohorts of Mechanics.

Table 1: Unit comparison

Attribute	Dynamics	Mechanics
Face-to-Face Contact Hours per Semester	Lectures: 2 hours/week (main) and 1 hour/week (maths supplement) Tutorials: 1.5 hours/week Computer Labs: 5 x 2 hours	Lecture: 2 hours/week Tutorials: 1.5 hours/week Experimental Labs: 2 x 2 hours
Assessment Items	Problem Solving Task, Computer Lab Assignment, Final Exam	3 × Online Problem Solving Quizzes, Group Design Project, Final Exam
Cohorts	Dyn-1: Semester 1, 2016 Dyn-2: Semester 2, 2016 Dyn-3: Semester 1, 2017	Mec-1: Semester 2, 2016 Mec-2: Semester 1, 2017

A set of WEVs were developed for each unit, such that each video focused on a single mathematics-based engineering problem, usually selected from the textbook, which aligned with the key content covered in face-to-face classes. Typically three to four WEVs were produced for each weekly topic, with the problems chosen such that they ranged in difficulty from simple to challenging. WEVs were structured to guide and enhance student learning. Each WEV opened with the question being introduced by the instructor, who then broadly discussed the problem solving approach to be employed, before working through the example systematically step-by-step by writing on the screen. Audio was used to narrate the process, emphasising connections between steps and the underlying principles as recommended by Clark and Mayer (2008). Common mistakes and misconceptions were clarified. Diagrams and visuals were used where appropriate to better communicate key concepts (Mayer, 2001). Videos were typically five to twenty minutes long. The videos were released to students at the end of the relevant week as a supplementary follow-up activity.

The WEVs were styled to break down the barrier between the instructor and the viewer, to maximise 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 where the problem is solved in front of an audience. 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 kept as short as possible to maintain the attention of the viewers.

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 revising lecture material and for exam preparation (Whatley & Ahmad, 2007).

In terms of practical implementation, the videos were captured using a Microsoft Surface Pro computer with the pen accessory, using the software programs of Microsoft OneNote, Microsoft Screen Expression/Screencast-O-Matic and Microsoft Movie Maker. The videos were uploaded unlisted to a YouTube channel and then embedded within the learning management system (LMS) Blackboard.

A data collection strategy incorporating both quantitative and thematic data was used to assess student-video engagement, interaction and attitude as well as the impact of WEVs on perceived academic performance. Students were surveyed anonymously at the end of each semester to elucidate their interactions and attitudes towards the WEVs. 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 5 minutes to complete. 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. The first dynamics cohort (Dyn-1) was not surveyed. Viewing statistics for all cohorts were collected from YouTube and the LMS.

Results & Discussion

To understand the impact and effectiveness of WEVs in MH-UEU, three main areas were analysed; viewership statistics, student interactions with WEVs and impact on perceived academic performance. Table 2 presents key metrics of the WEVs across the five cohorts. It is immediately apparent that students highly utilised the WEVs with a total of 24,478 recorded views, averaging 14.3 views per student. Views per student increased across consecutive cohorts. The increased viewership is attributed to improved awareness of the WEVs by the student body following a promotional drive by teaching staff. This was implemented in response to feedback that students were unaware the WEVs existed until late in the semester (a common problem experienced by other developers of WEVs, e.g. Kay and Kletskin (2012)). The time viewed per student is mixed for consecutive cohorts, which may be attributed to students selectively viewing sections of the videos discussed below.

To analyse this further, WEV viewership throughout the semester was explored (Figure 1). For Mechanics cohorts, two notable peaks in viewership were observed coinciding with quizzes held in weeks 4-5 and 8-9 (a third quiz was held in weeks 14-15 but this is hidden by end-of-semester study). The quizzes were only open for seven days which likely contributed to concentrated increases in viewership during these periods. Conversely, dynamics cohorts showed fairly steady viewership throughout the semester, with a slight dip near the end of semester when students were likely finalising assignments (weeks 11- 13). Interestingly, no major change in viewing is evident around the problem solving task due date (week 9) despite students reporting using the WEVs for this assignment. This may be because the assignment was released several weeks before the due date so assignment-related views were spread over a wide timeframe. Most significantly, a large peak is observed at week 15 for all cohorts, making up 57% of the total views. This peak corresponds to the final exam. These findings infer assessment is the largest driver of WEV viewership, which is largely unsurprising given that assessment tends to be a driver for student learning (Brown, 2005).

Table 2: Key metrics of WEVs across cohorts

Attribute	Cohort				
	Dyn-1	Dyn-2	Dyn-3	Mec-1	Mec-2
Students Enrolled	270	160	211	685	387
Total Videos	42	44	44	55	55
Total Views Recorded by YouTube	3408	2501	3393	8476	6700
Total Hours Viewed from YouTube	361	203	332	672	568
Average Views/Student	12.6	15.6	16.1	12.4	17.3
Average Minutes Viewed/Student	80	76	95	59	88
Survey Respondents	N/A	33	48	77	90
Response Rates %	N/A	21	23	11	23

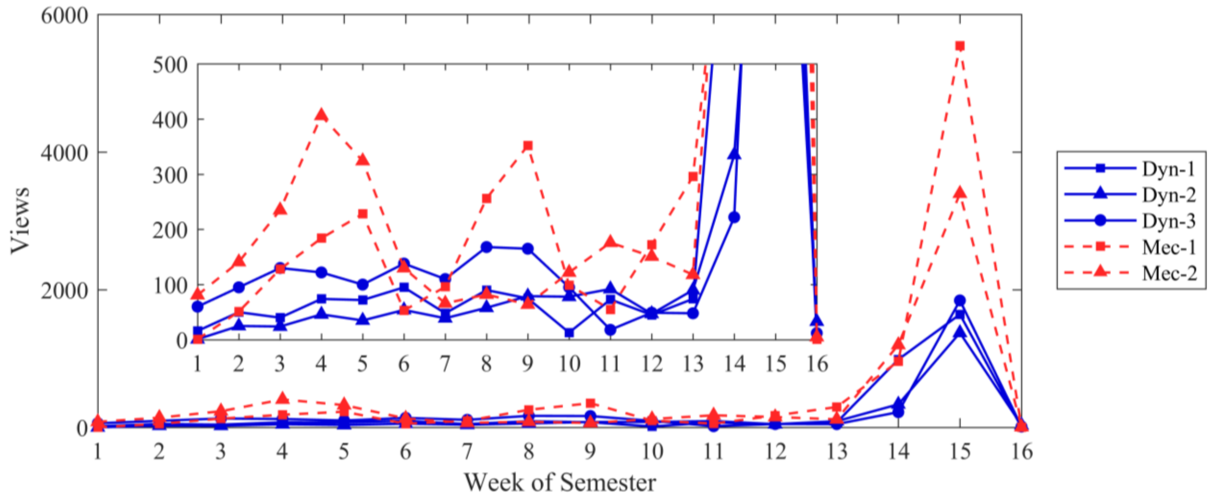

Figure 1: WEVs views per week from YouTube (inset zoomed in)

Hypothesising that WEVs encourage deep learning, student interactions with WEVs were investigated via the end of semester survey. Students were asked about their motivations for using the WEVs with results shown in Figure 2a. Both units show similar trends, with the vast majority of students reporting exam revision as a key driver; this is in line with the above viewership analysis. Despite assessment being the dominant driver for WEVs usage, between 30% and 50% of students reported using WEVs in an ongoing capacity during the semester for consolidating learning in face-to-face classes, to make up for missed classes, and to clarify understanding of challenging concepts. A small minority of students reported using the WEVs as a replacement for tutorial attendance. This suggests WEVs provide an effective blended learning experience which has minimal impact on reducing class attendance.

It is interesting that fewer students used the WEVs for assignments than for the exam. This may be explained by assignments setting a well-defined task compared to exams, for which students only know the broad topics being assessed. This means there is more value in reviewing a large number of problems for exams, such as those in the WEVs, in order to prepare for all possibilities. Furthermore, the assignments in both units tended to test content soon after it was taught compared to the exams which assessed content taught weeks in the past. Thus the WEVs became an excellent tool for systematic revision, supported by student

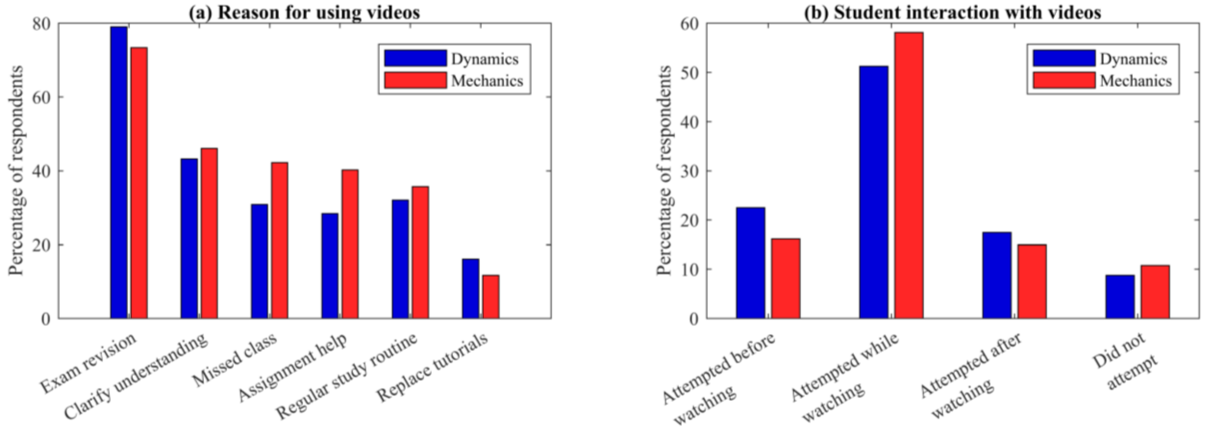

Figure 2: (a) Reasons students used the WEVs from survey responses, (b) Student responses to how they typically interacted with WEVs

comments such as, “I have looked at the videos as part of my revision … they are a great refresher.” This demonstrates WEVs are well-suited to units with significant final exams. The similarity of an assignment’s style to the WEVs can also help to pinpoint the types of units 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 the quizzes and just 25% for the group project. The quizzes asked questions similar to the WEVs, while the project was very different, requiring 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 assignment help, 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 units with assessment strategies centred on testing problem solving skills with questions similar in style to those presented in the WEVs.

Figure 2b shows how students interacted with the WEVs. Approximately 90% of students solved the examples before, during or after watching the WEV and thus employed an active learning approach, compared to only 10% of students who did not attempt the examples and consequently used a passive approach. 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).

To further explore student-video interactions, thematic analysis was conducted on open responses where students described how they interacted with the WEVs. The first major theme identified was using the video controls of pausing, rewinding and skipping. Students most 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.” 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 individualise their learning and review aspects they find challenging at their own pace. This self-paced learning afforded by the video medium has previously been identified as an area which students enjoy (Chester, Buntine, Hammond, & Atkinson, 2011).

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 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 examples from the textbook, evidenced by comments like, “Watched the video and applied the theory to another question.” This implies the WEVs can serve as a launching pad for further study. This 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.

The 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 3(a-b). This shows most students strongly agree the WEVs had a positive impact on their technical content knowledge, and they perceive this would result in better grades in the unit. 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 memorising solution processes, but rather learning the content on a deeper level. Figure 3c shows student attitudes toward the WEV resources are extremely favourable, with the majority strongly agreeing that they would use WEVs if made available other similar units. This was also echoed frequently in the open responses, again strengthening the argument that these WEVs would be suitable for other units.

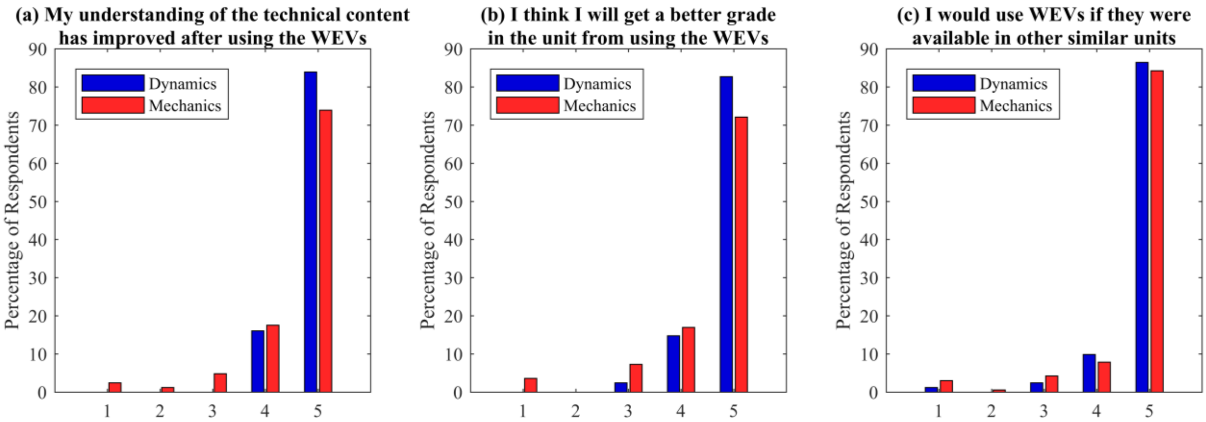

Figure 3: Likert scale responses to survey questions (1=strongly disagree, 5=strongly agree)

Conclusions

WEVs are well-suited to MH-UEU where solving worked-examples is a key teaching tool. Students are most likely to engage with the WEVs around the exam preparation period, with secondary engagement drivers being to reinforce content throughout the semester, make up for missed classes, clarify understanding of difficult concepts, and help for assignments which ask questions similar in style to the worked-examples. 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.

Students overwhelming interact with the WEVs using an active learning approach by independently working through the questions, often using the WEVs for hints when they get stuck and to verify their solutions. This is enabled by the video controls of pausing, skipping and rewinding which allow students to personalise their learning by concentrating on sections of the WEVs which they find challenging. Students report that they understand technical content better and expect to achieve better grades in the unit from using the WEVs. Students overwhelmingly agree that they would use WEVs if they were developed in other similar units. As such, it is shown that WEVs can be an effective tool for embedding blended learning approaches within MH-UEU.

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Ethics Approval

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

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