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Investigation of engineering student engagement and behaviour in an online second-year thermal science course

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Abstract: Abstract: This study is an investigation of online engineering undergraduate students' usages of online videos and embedded formative assessments in a second-year thermal science class. The findings from this study indicate that online students use online videos of course lectures in different ways. While some students watch each video only once, some students watch videos multiple times, and answer embedded assessment questions each time. This data can be used to describe student usage patterns and correlate student usage of videos with mastery of course content and academic achievement. The implications of gaining a better understanding of student usage patterns and their correlation with student performance will help engineering instructors who teach in online venues to more effectively use formative assessments and new technologies, as well as help instructors demonstrate the impact of effective study skills and routines for online students.

Keywords: online learning; formative assessments; student performance

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1. Introduction

Online learning in engineering is one of the next frontiers in educating large numbers of engineering undergraduate students. Recent advances in Massive Open Online Courses (MOOCs) through universities have proven that there is value and interest in offering highly technical courses to students around the world(London & Young, 2016). Other disciplines have employed online learning to a much greater extent than engineering has, partially due to the nature of engineering education as it has been taught traditionally, and also because of the slow nature of engineering as a discipline toward change in the academy(Bourne, Harris, & Mayadas, 2005). However, online engineering education has the potential to offer high-quality education to students who may not be able to complete a resident program, for a variety of reasons(Bourne et al., 2005; London & Young, 2016).

With this advantage in mind, it is of utmost importance to understand student usage and academic success of students who are taking courses through online venues. Student usage of online resources and correlations with academic success (this is an odd formatting line break) can provide a "snapshot" of ways to improve student learning through the course, harness new technologies to better meet the needs of students; and motivate students to use their resources to construct their knowledge within the engineering domain.

2. Review of the Literature and Theoretical Framework

A. Relevant Literature

With advances in online learning and technology, the opportunities to educate wider and more diverse populations of students around the world exists. It allows for both synchronous (at the same time) and asynchronous (at different times, as in on-demand) instruction. However, instructors sometimes have a difficult time incorporating active learning and formative assessments into the classroom, which are proven to be an effective mechanism to enhance student learning and receive feedback on student misconceptions and difficulties with the material(Felder & Brent, 2000; Violante & Vezzetti, 2014). In a sense, novel technologies cause instructors to revert back to traditional "chalk and talk" methods of pedagogy, when all existing literature in educational psychology and engineering education research points toward the necessity of new pedagogical models(Abel, 2005; McGee & Reis, 2012; Swan, 2003).

One difficulty for online instructors and course design is that online and asynchronous venues obviously cannot use the same venues for formative feedback. Comparative studies of online classrooms generally have been positive, noting similar learning outcomes (as measured by traditional classroom performance, grades, and tests, etc.) such as those reported by Twigg(2003)and Means et al.'s meta-analysis of online learning for the U.S. Department of Education (2009). However, the online learners in the compared studies reported here generally took more time to complete a course, which meant that the educational experience was qualitatively different.While educational researchers debate the ability to translate highly technical material (such as laboratory learning) into online courses (Bourne et al., 2005), most scholars agree that the quality of education matters as much or more than the venue. High quality learning environments, whether in online or residential settings should be based in authentic activities and involve strong interactivity with the material and other students(Herrington, Oliver, & Reeves, 2002; Reeves, Herrington, & Oliver, 2002; Richardson & Newby, 2006)and it is in this junction that we promote the incorporation of real-time formative assessments embedded into recorded classroom video. The use of the embedded questions within the on-demand video which replicate the clicker questions delivered to the resident students also serve to provide a periodic break in the instructional lectures to promote reflection and feedback regarding the lecture content. This also aids the online students when viewing the on-demand video lectures to break the recorded lecture in to shorter duration segments which aides maintaining the student's attention.

Although many scholars have investigated the overall learning outcomes between online and resident students in order to prove the value and educational feasibility of online learning, only a few of those studies in engineering curricula (see Ellis, Goodyear Clavo& Prosser, 2008, for an example studying engineering student discussions in face-to-face and online environment as they worked on a project).MOOCs in engineering are much more commonly reported, especially for fields such as software engineering(Dasarathy, Sulliban, Schmidt, Fisher, & Porter, 2014; Fox, Patterson, & Walcott-Justice, 2014). A few specific universities, such as the Massachusetts Institute of Technology (MIT) and Stanford University have been leaders in MOOCs and Small Private Online Courses (SPOC, a term coined by Fox et al.(Fox et al., 2014)) have been revolutionary in advancing the role of online learning in engineering education specifically(Iqbal & Zang, 2014).

Much literature related to MOOCs is programmatic and evaluative in nature rather than theory-based probes into the nature of engineering education and learning. In addition, most studies measure total learning outcomes by summative assessment and educational achievement (such as exam grades, final course grades, and GPA). Researchers of online learning do promote the use of authentic activities within courses in order to help students relate course material to real-world situations and enhance engagement (Reeves et al., 2002; Saade, He, & Kira, 2007; Swan, 2003).

Another topic that is understudied in the area of online engineering education generally is student behaviour patterns within courses, and how these usage patterns may affect content mastery and academic performance. While education scholars have studied the communication experiences and perspectives of online learners in asynchronous classrooms(Song, Singleton, Hill, & Koh, 2004; Vonderwell, 2003), models are proposed to optimize online learning in hybrid (resident + asynchronous online) settings (Twigg, 2003) or in online settings using formative in-class assessments as data outside of discussion forums(see Vonderwell, Liang, & Alderman, 2007). This lack of research may be partly due to the fact that instructors may not embed formative (informal) assessment mechanisms in online classes because of the lack of real-time feedback, and/ or are not aware of models for assessment in online settings.

B. Theoretical Framework

The theoretical framework that provides the lens by which to conduct and interpret this research is Bransford, Brown, and Cocking's (2004) How People Learn framework, which is a constructivist framework positing that optimal learning for all people occurs when the educational venue is learner-centric, assessment-centric, knowledge-centric, and community-centric. A representation of the How People Learn framework is shown in Figure 1. The intersecting facets of learner-, knowledge-, and assessment-centers show the importance of all educational activities target the ways in which the learner best learns, presenting students with the most important course content for their academic and professional success, while embedding in well-designed assessments that strongly align with the curricular

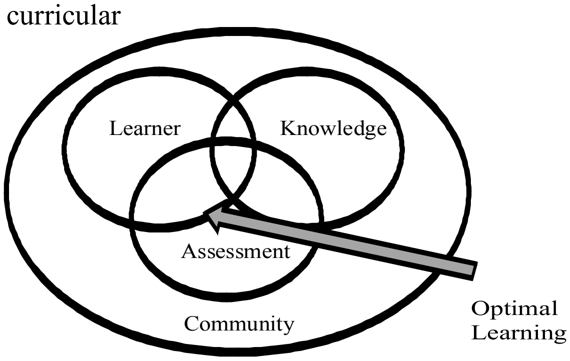

Figure 1: How People Learn Framework
(Bransford, Brown, & Cocking, 2004)

priorities of the courses. All these facets are embedded within the community-centric component of the model, which argues that all learning is inherently social (i.e. all learners learn from each other and also relate concepts to the real world disciplinary community). We posit that the use of formative assessment mechanisms such as "clickers" and embedded formative assessment questions in online learning venues exhibit strong aspects of all these facets. They engage the learner throughout a technical lecture (learner-centric), assessing students' grasp of the main tenets of the course (knowledge- and assessment-centric). The immediate discussion of the class answers with the whole class is a community-centric approach to learning, helping students understand where the rest of their classmates "are" in terms of conceptual understanding. Our research questions seeking to understand the behaviourof students as they approach their online learning venue is further evidence of the learner-centeredness of the initiative.

C. Research Objective and Significance

The purpose of this research is to use high-level descriptive statistical analyses to describe the video usage of 30 online learners enrolled in a second-year mechanical engineering thermal science class. Research questions that will be answered are as follows:

1. How do online engineering students use the online videos (how many times watched, how long do they watch?)
2. Does student mastery of course content correlate with usage patterns? If so, how?
3. What can student usage patterns offer to the instructional community regarding best practices for helping students achieve course learning aims and objectives?

3. Study Context

The context for this study is a 200-level (second year undergraduate) engineering thermal science course, that is taught annually to a class of approximately 600 students. Resident students at Penn State University comprise about 30of the students, and the rest take the class online through Penn State University. Within the class, great efforts are made to subscribe to best practices in teaching and learning, especially incorporative active learning and formative assessments to students within each class period. For resident students, formative assessment questions are asked in class to see if students understand the content, have misconceptions, and/or are able to apply course principles to simple problems. These questions are asked using "clickers" to capture student responses in real-time; the instructor then discusses the responses and the correct answer, working to identify areas where students need further instruction.

For online learners who are watching videos of the course asynchronously (i.e. not at the same time as the actual class is happening) it is impossible to use "clickers" in the same way. However, using Camtasia™ software, the same formative assessments asked in class can be embedded within the instruction video, where students have a set amount of time to answer the question. The data for student answers is recorded and similarly used to identify misconceptions. While the use of "clickers" and embedded formative assessment mechanisms for online learning has been discussed by two of the authors in prior work (Kulkarni & Iwinski, 2016) the behaviour of students approaching their online coursework has yet to be studied.

4. Methods

The data is comprised of formative assessment results from only online students enrolled in the thermal science class. Formative assessment results were recorded for 28 lecture sessions, covering a total of 48 multiple choice items. Since students are allowed to re-watch and re-take the formative assessments (correct answers are rewarded by participation points in the class grade), there were more data points (cases) to be analysed for each student. A total of 34,543 cases (i.e. data points) were analysed using SPSS statistical analysis software for basic correlations and descriptive statistics.

5. Results

A. Correlations between student success in formative assessments and video behaviour

The first question probed was the overall success rate of students as they answered the question. Educational best practices recommend that student formative assessments should range between 60%-80% correct in order to prove that the course is meeting learning objectives. "Item difficulty" as measured by percentage of correct responses fell within the best practices range indicating strong formative assessment effectiveness. Students answering the item incorrectly tended to watch a lower percentage of the linked video than students answering the item correctly ($R_{pb} = -.047$, $p = .000$.) This correlation was small but statistically significant, which is statistically illustrative of a low-stakes, formative assessment learning environment.

Over a third of the items (37.5%) were statistically significant correlations between video watching and formative assessment success. These correlations gave voice to the interplay of video paired with immediate formative assessment in two scenarios: 1) items where students watched almost all of the video and then scored above the mean in correct responses, and 2) items where students watched less than 69% of the linked video and scored below 72% correct responses. Let us discuss findings from both scenarios.

Scenario 1 is best exemplified by the four items tested in Lecture Five. This lecture was selected to be an example because student viewing behaviours were on average above the overall average of 69% video watched.In Lecture 5 (L5), Question One (Q1) checked for knowledge associated with the introductory lecture concepts. Ninety-two percent of students of the students answering the item correctly only watched 64% of the video associated with the first item, with some students only watching as little as 22% of the video. Results are shown in Table 1.

Table 1: Correlation between formative questions answered correctly and % video viewed for positive student behaviours

Scenario 1: Students watched more than the average of lecture videos							
Item	N	% Correct	SD	% Video Viewed	SD	R_{pb}	p-value
Q1	761	92	.268	64	.420	.128	.000
Q2	746	87	.335	97	.096	.101	.006
Q3	741	81	.390	100	*	*	*
Q4	675	83	.376	71	.376	.253	.000

As the lecture's conceptual and procedural knowledge demands increased, almost all of the class viewed the Question Two (Q2) and Question Three (Q3) video segments, and the students scored above 80% correct answers in Q2 and Q3 formative assessments. Question Four (Q4), the closing concept of Lecture Five, had a drop in percent of video viewed but the percent correct remained stable. These findings indicate that student knowledge from concepts tested in Q2 and Q3may have helped students prepare to answer Q4.

Scenario Two is best exemplified by four items from various lectures. As Table 2 illustrates, fewer students scored above the study's 72% correct answer average, and students video viewing fell below the study's 69% average.

Table 2: Correlation between formative questions answered correctly and % video viewed for positive student behaviours

Scenario 2: Various lectures where students watched less than the average amounts of the lecture videos							
Item	N	% Correct	SD	% Video Viewed	SD	R_{pb}	p-value
L2, Q1	856	52	.500	59	.414	-.346	.000
L6, Q2	753	49	.500	62	.413	-.177	.000
L7, Q1	734	55	.498	67	.408	-.219	.000
L14, Q1	755	38	.485	57	.428	-.283	.000

This scenario shows a case where students for some reason did not leverage the videos' instructional scaffolding to help them close their learning gaps.

6. Discussion

A. Interpretation and Discussion of Results for Engineering Education Practice

As discussed in the literature review, many studies have noted that formative assessments increase student learning. However, this study adds to this conversation, showing that ultimately in online settings, students are responsible for fully committing to their own learning, which includes engaging with the lecture. The correlations between % video watched and performance on the formative assessment activities are indeed intuitive, but in online settings (unlike in resident settings) there are fewer opportunities to require students to fully engage with the material.

There are multiple opportunities for engineering educators to use the results from this study in their own classroom. Firstly, the incorporation of formative assessments is critical in all educational settings, but especially for novel new learning environments such as online venues. Secondly, it would be compelling to students to cite this study at the beginning of an online course, showing the statistical correlation between video watching and success in both the formative assessments as well as in overall course grade. Then, students may be motivated to more fully engage with and watch the online lecture videos.

Additional issues to investigate within this model for instructional delivery are using the collected data to identify if students view the on-demand video with embedded questions in a paced progression to benefit from the Spacing Effect, as opposed to binge viewing (Sisti, Glass and Shors, 2007). This examination of the students' pacing of access to instructional materials is also associated to their timely access to the online course textbook utilized within the course. We are curious if the pacing of student access of these online resources affects the students' performance related to the formative assessments.

A further recommendation is for smaller engineering classes. The course studied in this paper is uncharacteristically large, but the findings still can be applied to smaller classes. If other engineering educators run their own statistics, they may be dismayed by "small sample sizes" due to small class sizes. However, in these cases, the authors urge instructors to consider the idea of "practical significance" over "statistical significance." Formative assessments are useful in engaging learners, and even if a few students are helped overall, then we as engineering education instructors are successful.

B. Opportunities for Future Work

Another area for future work is to conduct a comparative investigation of online and resident formative learning. A statistical analysis would confirm educational objectives and goals are being met as well as to ensure that pedagogical interventions have advantages for all types of learners, especially in hybrid online/resident classrooms. A study investigating student formative assessments (rather than summative assessments) would shed light on the ways in which students learn material (perhaps differently) for the first time, rather than in a summative (exam) context where students are being tested for their mastery of material after some time with practice.

Other areas for future work include correlating demographic factors of these second year university students with their usage of online resources and academic success. Factors such as socioeconomic status, high school grade point average, and geographic location, may be interesting factors to understanding potential differences between learners in online settings.

7. Recommendations for Engineering Educators

Based on the statistical data and informal feedback from students over several years, we definitely recommend embedding questions throughout the video lectures intermittently, just like the clicker questions in live classroom, which play a vital role in sustaining student engagement. Additional techniques, such as a small participation grade or unannounced pop-up format of the embedded questions gives them incentive to watch the lectures. If nothing else, it makes all of them,including the shy students, feel involved in the teaching-learning process!

8. Conclusions

This paper discussed student behaviours (how they used online videos) in an online second-year undergraduate engineering thermal science course. Two scenarios were presented as findings, showing student overall success when students used the videos to help them scaffold their own learning, and showing a scenario where students failed to use the videos to help them, and therefore did not succeed in formative assessment questions. Implications from this work motivate the importance of embedding formative assessments into online and other learning environments, and can be used to help online students see the value in engaging fully with course materials to facilitate their own knowledge and academic success.

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