International Journal of Engineering Education Vol. 34, No. 6, pp. 1798–1811, 2018
Printed in Great Britain
0949-149X/91 $3.00+0.00

Relationship of Blog and Video Usage Patterns to Academic Performance in Undergraduate Mechanics*

EDWARD BERGER
The Mechanical Engineering Education Research Center at Purdue (MEERCat Purdue), 1327 Armstrong Hall, 701 N. Stadium Avenue, Purdue University, West Lafayette, Indiana 47907, USA. E-mail: bergere@purdue.edu

EDWARD PAN
Technical Curriculum Developer, Amazon Web Services, Herndon, Virginia, USA.

This article describes a study about blogging and video technology usage and academic performance in a sophomore mechanics class with enrollment of 120 students. Two conceptual frameworks from learning science inform the discussion of student usage of social technologies and their impact on academic performance. This study employs data collected from 83 consented students on three surveys, technology usage data, and gradebook data to triangulate how students use the technologies, and what academic outcomes they achieve. Students are divided into four student cohorts, broken down by final course grade, and the results explore attitudes, usage, and technology adoption for each cohort. Open response data help describe the complex ecosystem driving student choices about technology usage as well as their academic outcomes. Although generally viewed as helpful, the video resources have a differential impact on student performance across grade bands. Students who earn good grades have better command of their resources (both the technology content, and their peers), using them both efficiently and effectively. Poor students struggle to use their resources effectively and are less active collaborators—either in person or online.

Keywords: social media; worked-example effect; illusion of explanatory depth

1. Introduction

Social media tools for teaching are becoming commonplace at all educational levels. This phenomenon stems from several factors, including increased access among students, improved authoring tools for content creators, and substantially enhanced usability of social media tools in general. In higher education, many individual instructors and textbook publishers produce video content to supplement specific courses and provide additional instructional resources to students. But there remain significant open questions about how such tools can be optimally used by students, and what impact they might have on student study behaviors or academic performance.

In this paper, we examine the role of two specific social technologies, blogging and video, in a required sophomore-level mechanical engineering course. Our primary research question is: how does the availability of substantial online resources for a course (a course blog and extensive video content) shape student study behaviors and academic success? We explore this question using a combination of quantitative and qualitative methods, including Likert-scale survey items, open response items, and gradebook data. The picture that emerges is that the available online resources are not uniformly embraced by students, with adoption and academic success influenced by beliefs about peers and collaboration, strength of study practices, and the perceived relative value of the online resources as compared to other available support resources. The results are interpreted in the context of several theoretical frameworks that shed light on student behaviors and choices about how they study and strive for academic success.

2. Background and conceptual frameworks

2.1 *Defining social media in this study*

We begin by defining our use of the term "social media" in this context. Originally emerging under the heading "web 2.0", social media today comprises an ecosystem marked by powerful authoring tools and ubiquitous user-generated content. Today's social media landscape includes a wide range of file types (audio, video, text) shared in a multitude of ways (YouTube, Vine, Facebook, Twitter), pushed to personal devices (especially mobile devices), often using location-based services. In the current study, we focus on two specific slivers of this broader ecosystem: (i) blogging for educational purposes, and (ii) use of video resources to support learning. We do not consider the full spectrum of social media tools, nor do we focus on the most current (for instance, Twitter). The origins of this study were shaped by the most rapidly-maturing technologies of the mid-2000's, as well as those that appeared to offer the highest relative

* Accepted 3 June 2018.

advantage compared to other technologies. First we briefly review blogging as an educational tool, and then we introduce the conceptual frameworks that will help us understand video.

2.2 Background on blogging

The scholarship on blogging as an educational tool continues to emerge. Much recent work has focused on the use of blogs for reflective work [1], self-expression [2], peer critique and collaboration [3], or highly-individualized authoring, and in many cases each student in a class has their own blog. In a meta-analysis of the literature, Sim and Hew [4] identified only a few studies that did not focus on the reflective and/or peer critique/collaboration elements of blogging. But the preponderance of the literature they reviewed suggests that students (albeit via mostly self-report mechanisms) believe blogs to be useful for academic purposes, for connecting with their peers in a social sense, and for socially constructing knowledge via peer review and feedback. This conclusion about blogs is generally supported in the more recent work of Hew and Cheung [5], who conclude that blogs generally have a positive impact on learning, especially when used within a constructionist pedagogy. The review by Tess [6] echoes the conclusions in several other works about blog research: the experimental design is somewhat lacking and more rigorous studies are in order. A more general conclusion about blogging in higher education is that its effectiveness is strongly related to the overall pedagogical design of the course, the specific intended purpose of the blog, the expectations for student usage, and the perceived utility of the blog by students. Pursel & Xie [7] present an overview of blogging practice and pedagogies at one university, although they observe that in their sample population about 21% of the students account for over 80% of the total original contributions (both posts and comments) to academic blogs. They suggest that one reason for the very high number of infrequent bloggers in their study was the lack of specific assessments related to blog activity. Overall, this literature makes it clear that a thoughtful integration of blogging into the pedagogical design of a course can be fruitful.

2.3 Conceptual framework 1: The worked-example effect

Understanding the affordances of video technologies for learning requires two threads from the literature. The first thread is the worked-example effect. Widely reported by Sweller and colleagues [8–11], the worked-example effect posits that student learning (i.e., schema acquisition and automation) can be effectively supported and accelerated by watching experts solve problems. The particular brand of worked-examples in this research is the video solution (described in detail later) that allows students to possess, play/re-play, and share recorded versions of expertly-constructed solutions on their own device. The essence of the worked-example effect is that expert problem solving processes—the processes and decisions that experts (by virtue of being experts) know to be correct—are presented to novice learners in a clear and concise way. The worked-example effect corresponds strongly to cognitive load theory (CLT), because the worked examples must be both constructed by the expert and used by the novice in ways that optimize cognitive load on the learner [12].

Evidence of the effectiveness of worked examples is reasonably convincing, especially in STEM domains such as physics [13], mathematics [14], mechanics [9], algebra [11], and electrical circuits [15]. Worked examples compare favorably to more standard instructional models, including actually solving problems [11]. Moreover, when extended with supporting pedagogical devices such as self-explanation prompts [14, 16], worked examples can provide a powerful platform for student learning.

And yet, Moreno concludes in a comprehensive review of the CLT literature, that "worked examples don't always work" [17]. While Moreno takes a strongly CLT-oriented view of this question, we can collect three other potential explanations for this situation. The first explanation is that students do not always know how to make optimal use of worked examples, favoring passive consumption over a more engaged and interactive relationship with the video. Using instructional explanations (i.e., providing expert commentary about why particular steps in the solution are—or are not—useful at a particular stage) can help students develop deeper conceptual understanding, as can prompting students to articulate self-explanations [18]. The second explanation has to do with the habits of "good" and "poor" students. Chi et al. [13] produce very persuasive evidence that poor students simply are not as sophisticated as good students, because they are not continuously probing the depth of their own understanding. This self-reflective practice in which good students constantly self-assess their understanding allows them to detect "comprehension failures" [13, p. 170] and immediately attend to them. In contrast, poor students often do not know that they do not understand the material because they lack this self-reflective approach of the good students. The third explanation is the so-called expertise reversal effect [19], in which reasonably sophisticated problem solvers (i.e., "good" students) can progress in their problem solving ability, surpassing the developmental stage in which worked examples are effective. In such cases, a variety of approaches that customize the worked example to the developmental stage of the student have emerged; fading is but one of these approaches [20–22] in which solution steps are selectively omitted (i.e., "faded") from the solution with the expectation that the student will fill in the missing steps.

2.4 Conceptual framework 2: The illusion of explanatory depth

The second thread in the literature provides some clues about why some users of the educational interventions might not achieve a very good academic outcome. Rozenblit & Keil [23] put forth the illusion of explanatory depth (IOED) to address the idea that people in general are not very good at estimating their own mastery of a particular concept *a priori* of an external assessment of their mastery. In a series of clever experiments, they showed that (i) people are generally quite poor at assessing their own knowledge (and typically over-estimate it), (ii) their assessments are especially poor in technical domains (what Rozenblit & Keil call "devices" and "natural phenomena"), and (iii) only after an external assessment does an individual's self-assessment more closely match their actual level of understanding. IOED is precisely the effect alluded to by Chi et al. [13] when they concluded that poor students "may not realize that they do not understand the material . . .", despite having consumed worked examples. Within the IOED framework, we expect that good students are better at assessing and, more importantly, challenging their current level of understanding than poor students are, consistent with the conclusions of Chi et al. [13]. Ylikoski [24] argues that IOED has multiple sources, including a failure to understand the difference between an explanation and a description. Here, we interpret "explanation" as a detailed and sophisticated exposition of how to solve a problem, what conceptual knowledge is required, and what steps (and in what order) advance the solution towards its conclusion. We interpret "description" as more of a procedural exposition, neglecting conceptual understanding and focusing more narrowly on the mechanics of the solution. Rozenblit & Keil [23] might as well have been describing video-based worked examples when they conclude (p. 552): "the prominence of visible, transparent mechanisms may fool people into believing that they have understood, and have successfully represented, what they have merely seen."

3. Pedagogical design

The Dynamics course in this study had a final enrollment of 120 students, mostly drawn from mechanical and aerospace engineering and almost entirely composed of undergraduate sophomore students. This three-credit class met three times per week, 50 minutes per meeting, and each class meeting contained minimal "lecturing" on new concepts and ideas and engaged students in a larger block of collaborative problem solving and other active learning strategies. As such, this is considered to be an active classroom in which students are invited to collaborate with their peers, both in and out of class. The out of class collaboration took multiple forms, including face-to-face study groups and online collaboration via the course blog. The pedagogical stance of the course was very much constructivist, with the expectation that students could and would learn from each other and construct meaning in the course together.

There was a single division of the dynamics course, and many of the dynamics students were enrolled in the same set of sophomore-level courses, many of which also had a single division. The result is that as many as 80–100 students enrolled in dynamics had substantially similar course schedules for the semester, and they therefore saw each other every day, had the same homework assignments and deadlines, and generally moved as a group from course to course. The implication of this arrangement on collaboration habits is explored in detail later in the paper.

The course blog was the information backbone of the course, and it essentially replaced the course management system (CMS) used at the university. From the blog, students could access course resources, learn about homework assignments and due dates, download video resources, and enter dialogue with each other via the blog commenting features. The blog was designed for intuitive navigation, ubiquitous access, and easy communication. Built upon the WordPress platform, the course blog provided a single online presence for the course. Student usage of the blog was required, in two senses. First, homework assignments, due dates, exam preparation materials, etc. were only posted on the blog, so students had to access the blog to obtain these materials. Second, to incentivize collaboration using the blog, students were awarded "blog points"; up to 3% of their final grade in the course could be earned through various contributions to the learning community via the blog. These contributions could consist of asking/answering questions using the comment features, linking to interesting videos/articles germane to the course content, or creating original content (such as a problem solution) to share with the class. The notion was to develop the blog as a community resource by providing an incentive to participate.

Video resources for the course were developed and designed according to best practices [25], [26], and fell into two categories: (i) lecture videos, and (ii) video problem solutions. The *lecture videos* comprise motivation, background, concepts, and derivations, and were designed to provide concise representations of key technical content in the course. The classroom was not flipped, and students were not expected to watch the lectures before attending class. The lectures were available for students who missed class or simply wanted to review conceptual or background information. *Video solutions* presented step-by-step solutions to mechanics problems. Video solutions were narrated problem solutions in which the instructor explained not only the procedural aspects of the problem, but also expert insights required to make critical decisions about how to execute the solutions. These videos did not contain a talking head, and were instead screen recordings of handwritten tablet input synchronized with the instructor's narration on the thought process during the solution. The video solutions can be classified as worked examples with instructional explanations [18]. Students were not required to use either of these video resources.

Beyond the technology elements of the course, typical evaluations such as frequent homework, periodic quizzes, multiple midterm exams, and a final exam were delivered. All the technology was fully explained in class, with repeated reminders about the available technology resources and how to use them appropriately.

4. Methods

4.1 Participants

Of the 120 students enrolled in the course, 83 agreed to participate in the study and were consented for this purpose. Each participant was invited to complete three paper-based surveys throughout the semester, with a different number of respondents each time ($n_{pre} = 83$, $n_{mid} = 65$, $n_{post} = 69$) depending upon who attended class on the days the surveys were delivered. Students who nominally completed a survey might not have responded to every item on that survey. The pre-survey considered demographic data, test scores (i.e., SAT), questions about comfort with technology, and other baseline questions. The surveys largely focused on student usage and perceptions of the technology components of the course, and also asked about their work habits in the course. For instance, we asked about their collaboration habits: when, where, and with whom they accessed the technology resources for the course, and whether the technology aligned with their preferred approach to learning. In addition to the surveys, students were invited to participate in the public discussion on the course blog, so the digital record of their engagement on the blog was also collected. All their grades for all graded material in the course were used to correlate participant survey responses to academic performance.

4.2 Data collection

A final course grade for each student was computed as the weighted average of the graded assignments in the course, with exams receiving the most weight in the calculation. The resulting final course grade was divided into four grade bands: < 70%, 70–80%, 80–90%, 90–100%. This study used a variety of descriptive statistics and frequencies, as well as more qualitative approaches to analyzing the survey responses. Survey response data were grouped by grade band. Frequencies of categorical response data from the surveys were totaled for each band. Standardized frequencies (proportion of code frequency for a grade band) of responses were compared between bands.

The surveys contained both Likert-type and open response items. Survey responses were merged with gradebook data at the end of the semester, and the entire spreadsheet was scrubbed of student identity information. Open response items from the three surveys were coded for content using an inductive approach in which themes were emergent from the data analysis, rather than specified *a priori* [27]. This qualitative analysis was conducted using NVivo [28], while the quantitative analysis of survey data was performed using the statistical computing package R [29].

5. Results

The results of this study are presented in the next four sub-sections, which describe analyses of increasing focus. In Sec. 5.1, we provide descriptive statistics of survey results broken down by grade cohort, with the goal of revealing differences in attitudes and learning strategies about technology. Sec. 5.2 uses multidimensional visualizations to relate multiple usage variables to overall course grade, with the intention of revealing usage patterns that correlate to high performance in the course. Sec. 5.3 illustrates common usage patterns via four student exemplars whose performance in the course was either very high or very low. Sec. 5.4 introduces qualitative analysis of student open responses, providing further texture to several emergent themes and tying the analysis back to our theoretical frameworks.

5.1 Background survey responses, by grade cohort

We first consider survey data broken down by grade cohort, defined according to their final course average as "A" (average > 90%, 15 students), "B" (80–90, 35 students), "C" (70–80, 27 students), and "F" (average < 70%, 6 students). The overall final average for the course was 84.8% (SD: 7.1%). Throughout the course, 717 comments were posted on the blog's homework and exam threads by students, for an average of about 6 comments per student. Based upon student responses on the post-survey on which we asked about video consumption, we estimate that total consumption of lecture videos throughout the semester was 100–120 (an average of about 1.7 per post-survey respondent), while the total consumption of video solutions throughout the semester was over 1000 (an average of about 15 per post-survey respondent).

We first examined student attitudes about two issues: (i) collaboration/trust in their peers (both face-to-face and asynchronously via the course blog), and (ii) their preferred learning strategy. Our hypothesis was that how students actually use the technology will be influenced by their attitudes about collaboration (do they prefer to meet face-to-face, in a study group? do they prefer to work alone?) and about their approach to learning (would they prefer to read the textbook?). The supposition was that students who prefer face-to-face collaboration will be less active in their technology usage. Tables 1 and 2 show results for various survey items, broken down into cohorts by grade band, that provide a backdrop for subsequent discussion about technology usage.

Table 1 displays results regarding collaboration and students' trust in their peers, as captured on the post-survey from the end of the semester. Students across all grade bands believed that collaboration was beneficial for both their understanding of the material and their grade, yet only about half the students in total made collaboration a priority. The "F" cohort recognized the value of collaboration, yet did not prioritize it. This lack of peer engagement among poor students was consistent with an academic disengagement framework [30], as well as research on personality traits of college students [31]. Both these works indicate a lack of significant engagement with peers is a common trait of struggling students (what Brint and Cantwell call "interactional disengagement"). On the other hand, even quite successful students sometimes approached collaboration with caution; half of the "A" cohort indicated that collaboration was not a priority, and fully 1/3 did not think it was beneficial for either learning or for their course grade. Of the 51 students who believed that collaboration with peers was beneficial for both their grade and for their learning, 18 of them (distributed across grade bands) nonetheless *did not* make collaboration a priority.

Table 1. Survey responses: collaboration and trust in peers (post-survey, n_{post} = 69)

Item and Responses	P_A	N_A	P_B	N_B	P_C	N_C	P_F	N_F
Collaboration is a priority								
No	0.53	8	0.37	10	0.59	13	0.80	4
Yes	0.47	7	0.63	17	0.41	9	0.20	1
Collaboration is beneficial for learning								
No	0.33	5	0.11	3	0.14	3	0.20	1
Yes	0.67	10	0.89	24	0.86	19	0.80	4
Collaboration is beneficial for my grade								
No	0.33	5	0.22	6	0.18	4	0.20	1
Yes	0.67	10	0.78	21	0.82	18	0.80	4
Collaboration helps me understand concepts*								
Not at all	0.13	2	0.00	0	0.00	0	0.00	0
A little	0.13	2	0.11	3	0.19	4	0.40	2
Somewhat	0.33	5	0.52	14	0.48	10	0.40	2
Definitely	0.40	6	0.37	10	0.33	7	0.20	1
Trust the blog content								
Not at all	0.07	1	0.04	1	0.09	2	0.00	0
A little	0.07	1	0.00	0	0.23	5	0.20	1
Somewhat	0.67	10	0.52	14	0.18	4	0.60	3
Definitely	0.20	3	0.44	12	0.50	11	0.20	1
Homework threads are useful								
Not at all	0.13	2	0.00	0	0.09	2	0.20	1
A little	0.20	3	0.15	4	0.36	8	0.20	1
Somewhat	0.47	7	0.56	15	0.27	6	0.40	2
Definitely	0.20	3	0.30	8	0.27	6	0.20	1

Note. P_A = proportion of A-student respondents; N_A = number of A-student respondents; other columns are similarly labeled.
* For one item ("Collaboration helps me understand concepts"), one post-survey respondent did not respond, so the total responses for this item is n = 68.

Table 2. Survey responses: learning strategies and technology (post-survey, $n_{post} = 69$)

Item and Responses	P_A	N_A	P_B	N_B	P_C	N_C	P_F	N_F
How do you best learn (check all that apply)								
Do it myself	0.93	14	0.88	23	0.91	20	0.80	4
Lecture	0.20	3	0.31	8	0.23	5	0.00	0
Reading	0.27	4	0.35	9	0.18	4	0.60	3
Watching	0.40	6	0.58	15	0.64	14	0.60	3
Working w/ others	0.53	8	0.65	17	0.45	10	0.20	1
Other	0.00	0	0.04	1	0.00	0	0.00	0
Best learning strategy (check only one)								
Do it myself	0.80	12	0.65	17	0.59	13	0.80	4
Lecture	0.00	0	0.04	1	0.00	0	0.00	0
Reading	0.00	0	0.00	0	0.05	1	0.00	0
Watching	0.07	1	0.12	3	0.23	5	0.20	1
Working w/ others	0.13	2	0.19	5	0.14	3	0.00	0
Other	0.00	0	0.00	0	0.00	0	0.00	0
Access to the technology helped in the course								
No	0.40	6	0.22	6	0.55	12	0.60	3
Yes	0.60	9	0.78	21	0.45	10	0.40	2
Technology was useful to the way you learn								
No	0.20	3	0.04	1	0.41	9	0.40	2
Yes	0.80	12	0.96	25	0.59	13	0.60	3
The technology was essential to your learning								
No	0.80	12	0.59	16	0.55	12	0.80	4
Yes	0.20	3	0.41	11	0.45	10	0.20	1

Note. P_A = proportion of A-student respondents; N_A = number of A-student respondents; other columns are similarly labeled.

Asynchronous collaboration on the blog was also related to performance in the course. Students could earn 0, 1, 2, or 3 "blog points" for their online contributions as described above. Students who earned 0 blog points (i.e., were socially disengaged on the blog) had a lower final grade, on average, as compared to the more active blogging groups. The difference in final course average as compared to the 3-blog-points group was statistically significant at $p = 0.0006$ based on the raw averages (77.7% vs. 86.4%), and $p = 0.02$ when correcting the 3-blog-points group average by (-3) points for the blog points themselves (77.7% vs. 83.4%). Moreover, half the F students had 0 blog points, while 85% of the A students earned 3 blog points. Of the 9 students for whom peer collaboration was not a priority, and who earned either 0 or 1 blog points, 7 are from the C and F grade cohorts (with the other two from the A cohort). There was a population of students who were socially disengaged both in-person and online, and their performance in the class generally was worse than students with more social engagement. Our data suggest the technology resources were not an effective substitute for peer collaboration or other forms of in-person academic support. Some of the reasons why the technology was not an effective replacement are explored next.

Table 2 displays results regarding different learning strategies that students believed were the most effective for their learning, as captured on the post-survey. Students across all cohorts predominantly believed that the best way to learn something is for individuals to practice that skill or task for themselves. Watching someone else (perhaps in a video) also scored highly for students of all bands. Working with others was reported as an effective strategy by the "A", "B", and "C" cohorts, whereas the "F" cohort students preferred non-collaborative strategies. With their preferred learning strategy as context, students were also asked a series of questions about the value of the technology and its impact on their learning. Access to the technology was viewed to be helpful, although in the aggregate only about 1/3 of students perceived the technology to be "essential" for their learning. We believe this number could be slightly inflated as well, because in a very literal sense, the technology was essential—the only way to access the homework assignment was to consult the course blog. It is possible that some students took this literal interpretation of the question, so the 1/3 is therefore an upper bound on the number of students who viewed the technology to be "essential". The majority of students felt that the technology resources were useful for their preferred learning strategies, and from this we can infer that students were generally able to integrate the technology components into their other study habits. The specific question of precisely how the students used the technology is considered next.

5.2 Technology usage and its relationship to academic performance

Fig.1 is a jittered bubble plot showing the relationships among perceived usefulness of the lecture videos, perceived difficulty of the course (the two axes on the plot), the number of lecture videos watched (the radius of each bubble), and final course grade (the shading of each bubble). Jittering is a data visualization technique that adds a small amount of random noise to each data point so that individual data points are not plotted on top of each other [32]. Jittering is especially useful for categorical data, such as the survey response data shown here on the two axes of the figure. Bubbles which roughly align with, say, the "Somewhat Difficult" column on Fig. 1 should be interpreted as corresponding to a survey response in which the respondent perceived the course to be "Somewhat Difficult". The figure shows a generally low consumption of the lecture videos (most of the bubbles have a small radius), largely because they are perceived as generally not all that helpful—despite the high perceived difficulty of the course. Because class attendance was typically quite high, and because of the pedagogical design of the recorded lectures (background, concepts, and derivations, rather than problem solutions) there is little reason to expect that students would be avid consumers of the lecture videos. We would not expect a worked-example effect to be evident for the lecture videos, because their pedagogical design is not focused on problem solving. The inset to the figure shows representative open response comments collected on the post-survey about the lecture videos, and they reinforce the initial interpretation of the lecture video usage data. Student generally expressed that they liked the videos, but that they were not essential to their study habits because they: (i) had other alternatives that offer greater value (the textbook; their peers), or (ii) they attended lecture in person and have no need to view a recorded lecture.

Fig. 2 is a similar bubble plot reporting on the video problem solutions rather than lecture videos. Students who perceived the course to be more difficult were more active consumers of the video solutions, as might be expected. It is conspicuous that the higher consumers of the video solutions, and those that perceived them to be the most useful, were not all from the same grade cohort. Indeed, there were students who perceived high usefulness

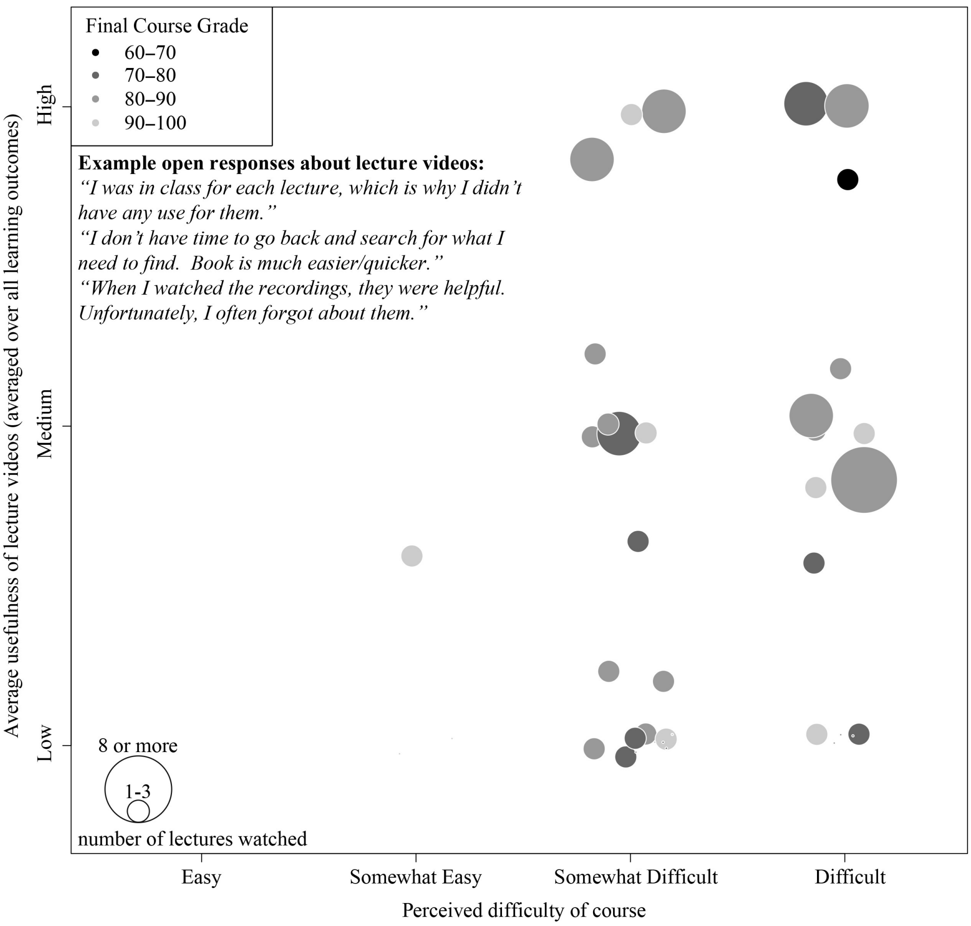

Fig. 1. Lecture video usefulness and consumption as a function of perceived course difficulty, by grade cohort.

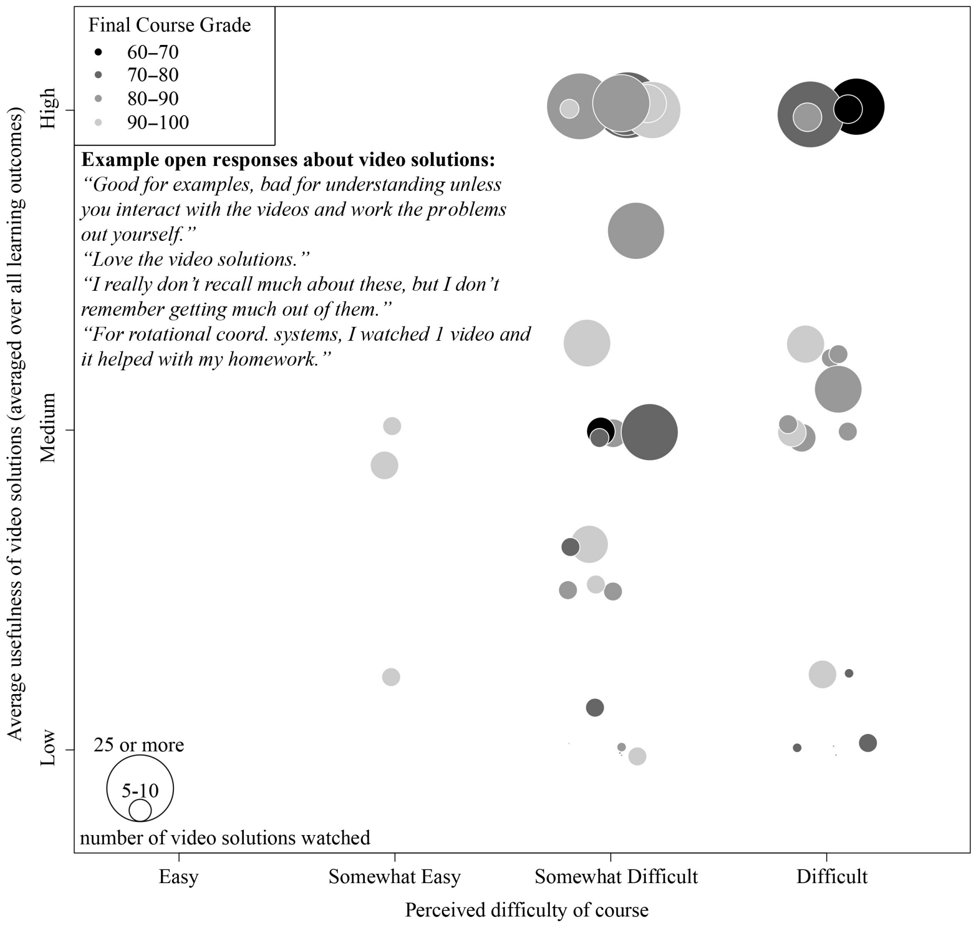

Fig. 2. Video solution usefulness and consumption as a function of perceived difficulty of the course, by grade cohort.

and experienced high consumption from all four grade bands used in this analysis. The video solutions were generally consumed at a higher rate than the lecture videos, largely because the video solutions involve actual problem solving and were therefore much more representative of the course assessments (homework, quizzes, and exams) than were the contents of the lecture videos. It is slightly conspicuous that students from the highest grade band also generally perceived the video solutions to be less useful than students from other grade bands. We speculatively put forth the idea that this may be an expertise reversal effect [19, 33], in which the best students, who are presumably already strong problem solvers, are not significantly supported by consumption of the video solutions.

Given that students perceive the video solutions to be helpful, it is worth looking further into precisely how the students use the videos. We asked students on the post-survey how they used the video solutions, and they chose from four options: (i) watch passively; (ii) watch and write while the solution is playing; (iii) pause and watch, in which students sequentially attempt to solve one step of the problem, then use the video to check their work; and (iv) solve the problem completely before watching the video to check their work. The order in which these four options are presented roughly corresponds to a hierarchy of cognitive processes, with "watch passively" demanding the lowest cognitive effort, and "solve before watching" demanding the highest.

Fig. 3 illustrates the relationships among perceived average usefulness of video solutions, how the video solutions are used, how many video solutions are consumed, and final course grade. The figure demonstrates several features of the video solutions. First, students who perceive higher value to the video solutions generally consume more of them, as expected. Second, and perhaps more importantly, students who engage with the video solutions using higher cognitive processes (i.e., those who pause and watch, or watch before solving, rather than passively consume) both perceive higher usefulness and consume more videos. Moreover, the cohort of students who engaged with the videos more constructively had better course performance, on average, than those who did not. This is the worked-example effect in action: the region of the figure that includes students

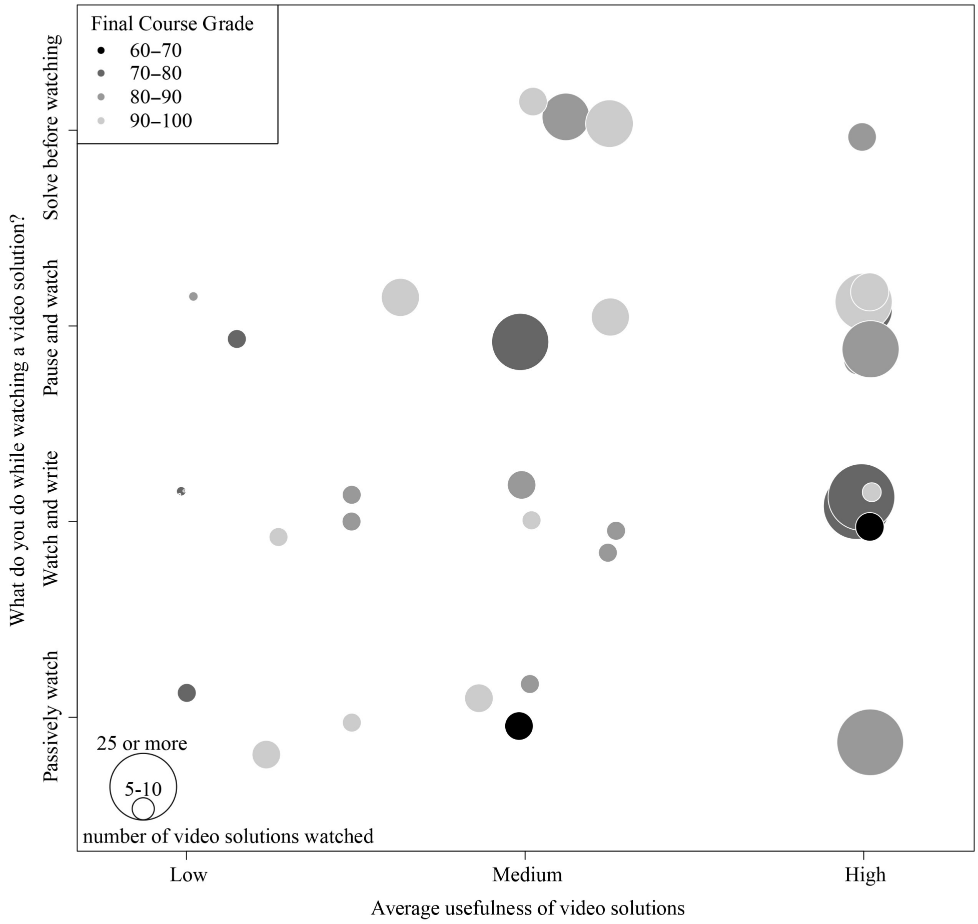

Fig. 3. Average usefulness of video solutions and consumption as a function of how the videos are used, by grade cohort.

who watch the videos passively also perceive low usefulness, and therefore do not actively and reliably use the video resource. In addition, students who either pause and watch, or solve before watching, have engaged in their own self-generated fading exercise by deliberately revealing steps of the solution only after they have attempted to work it themselves.

The survey results and course performance data presented above yield a partial picture of the student experience in this course. We assign trend-level significance to these results. A series of one-way ANOVAs did not allow statistically significant conclusions to be drawn from the data here, due to small sample size of the grade-parsed data. However, the quantitative data do suggest behavioral themes in students that require more data and analysis to completely reveal.

5.3 Patterns of usage and their relationship to academic performance

Table 3 defines characteristics of the lived experience of students, characterized according to three axes: (i) attitudes and perceptions about technology and collaboration, (ii) behaviors and technology resource utilization, and (iii) academic performance in the class. Each axis has several sub-indices that provide further detail for each student. Table 4 shows illustrative data along each axis and index for several students who achieved two different performance outcomes in the course. In all cases in Table 4, the value along any particular index is scaled, by the maximum value in the range of that index, to be 1, so a larger value indicates "more" of that index (more videos consumed, higher priority placed on collaboration, higher exam score, and so forth). The minimum value for each parameter in the table is 0.

Table 4 suggests that there are multiple ways to succeed in the course, and student-level characteristics (both cognitive and non-cognitive) play substantial roles in the learning process [34]. Broadly speaking we saw three categories of students in the data. Student 40 was an exemplar of the category of students who could not find the optimal formula for academic success even within a resource-rich environment. Student 40 indicated: "I felt that the information provided didn't need technological assistance, or at least [not] to such an extent." When asked why the technology was not essential,

Table 3. Data categories and sources for student characterizations presented in Table 4

[Abbreviation] Axis/Index (data source)	Range
Attitudes and perceptions (survey data)	
[A-P] Is collaboration a priority?	0 = no, 1 = yes
[A-C] Collaboration score*	0 (not at all)–6 (very actively)
[A-T] Trust in blog content authored by peers	0 (not at all)–3 (yes, definitely)
[A-Co] Comfort with technology in general	0 (not at all)–4 (yes, very)
[A-U] Is technology useful to the way you prefer to learn?	0 (no)–1 (yes)
Behaviors and resource utilization (various sources)	
[BR-B] Blog contributions (factual usage data)	0 (none)–3 (many)
[BR-L] Lecture videos watched (survey data)	0 (none)–3 (more than 8)
[BR-V] Video solutions watched (survey data)	0 (none)–8 (more than 35)
Academic performance (gradebook data)	
[P-H] Homework average	0–100%
[P-Q] Quiz average	0–100%
[P-E] Exam average	0–100%
[P-C] Course average	0–100%

* Collaboration score is a composite measure of 4 items from the post-survey about student views of collaboration: is it a priority, is it beneficial for learning, is it beneficial for your grade, it is beneficial for understanding concepts.

Table 4. Student-level metrics from the post-survey illustrating a variety of attitude, resource utilization, and academic performance patterns. Category abbreviations are found in Table 3

Student Number	Attitudes and Perceptions					Academic Performance				Behaviors and Resource Utilization		
	A-P	*A-C*	*A-T*	*A-Co*	*A-U*	*P-H*	*P-Q*	*P-E*	*P-C*	*BR-B*	*BR-L*	*BR-V*
9	1	1	1	0.75	0	0.87	0.50	0.63	0.68	0	0	0.86
40	0	0.33	0.67	1	0	0.75	0.45	0.67	0.70	0	0	0.43
55	0	0	0	1	0	0.99	1	0.99	0.99	1	0	0
74	1	1	1	1	1	0.99	1	0.88	0.92	1	0.33	0.29

this student identified one of the potential downfalls of the video solutions: "Some parts, like video solutions, have a tendency to trick you into thinking you understand something." Further, they are "good for examples, bad for understanding unless you interact with the videos and work the problem out yourself." This clear allusion to both of our conceptual frameworks (worked-example and IOED) suggests a potential downfall of video-based technologies for some students: if the solution looks too easy (i.e., if the learner's cognitive load while watching the video is too low), then schema acquisition will not take place, and in fact the worked example might be doing more harm than good.

Two other categories of student both earned high grades in the course. The first category, represented by Student 74 in Table 4, prioritized in-person collaboration over the use of technology. Students in this category generally believed that collaboration was useful and helpful for their grade, and that collaboration with both peers and course resources (such as video solutions) would be beneficial for their course performance. The second category, represented by Student 55 and containing a very small number of students, prioritized conscientiousness and basic self-reliance, using both technology and peers infrequently (if at all). The traits of students in this category, including study skills, conscientiousness, time management, etc., are likely well above average compared to their peers.

5.4 Open response analysis

These ideas can be elucidated further if we consider the open responses to survey items for all students. A total of 14 open ended questions appeared on the mid- and post-surveys combined, with a total of 264 unique responses collected. These 14 questions probed student opinions and attitudes in 5 categories: the course blog, lecture videos, video problem solutions, collaboration, and the technology used in the course in general. Those 264 responses were coded using an inductive process [27], revealing 6 high-level themes: the five categories listed above, as well as the emergent category we called "external pressures". "External pressures" captured feedback from students about their overall educational ecosystem and is detailed below. Underneath those 6 high-level themes, we identified 19 secondary themes to provide more texture to the analysis. Some responses were coded into more than one category, yielding a total of 334 codings for the 264 individual responses.

5.4.1 Overview of the themes

According to the open responses, students generally perceived the video solutions to be helpful, the lecture videos to be somewhat useful, and the blog to be a good backbone for delivering course material (although not for communication and collaboration). A surprising number of students claimed that they had significant technical difficulties (accessing the blog or viewing the videos); this is surprising because we invested substantial effort in shaping the technologies to be as user friendly as possible. Many other students reported that they often forgot that the lecture videos and video solutions were available to them, and as a result they did not use those resources. The mainstream opinion was that the technology deployed in the course was "helpful" rather than "essential".

5.4.2 Prominent Theme 1: Technology and pedagogy

Many students addressed pedagogical questions, either directly or indirectly, in their open responses (a total of 26 responses in this category). For example, 12 of the 69 respondents to the post-survey indicated that they "like", "generally use", or "prefer" the textbook rather than the technology for learning the material. For these students, a technology-based pedagogy was not especially compelling, and they preferred a more traditional method for learning. We received 6 comments specifically asking for the instructor to stop using technology for in-class work, and instead use the chalkboard (example: "I just like traditional chalk-on-board teaching. Technology is an unwanted hassle."). We received 21 comments indicating that the technology generally did not align very well with the student's preferred approach to learning. Many students cited either their own self-reliance, or their preference for in-person collaboration through their study group or instructor office hours, as reasons why the technology did not easily fit into their academic workflow. One student commented "I can solve basically most of the problems on my own", while another said "if I'm struggling with the material that much, I'll go to office hours". Students also expressed support for, and the challenge of, the course blog for asynchronous communication. Several students viewed the idea of posting comments to the blog as quite helpful to their own learning; for example: "it helps me learn [when I have] to explain things to people and to see an explanation by my peers". But others expressed the challenges of asynchronous, written communication: "Hard to express issues when commenting on blogs", suggesting a challenge with articulating either a question or an answer in writing.

5.4.3 Prominent Theme 2: Collaboration

We received 26 comments about collaboration, including both in-person and asynchronous collaboration using the blog. Of those, the overwhelming majority (about 80%) specifically indicated that their preferred method of collaborating is face-to-face, in a study group or in office hours. Of those who indicated they valued the blog as a collaboration tool, none indicated that they *prefer* it to face-to-face options; rather they only indicated that they liked the blog for communication and collaboration. One student (who earned a grade of C in the course) targeted the ecosystem in which the students live: "It [the blog] made an already complicated subject even more complicated. *I'd just use [our institution's course management system] like every other class to post HW/announcements*." (italics ours). There are two important observations here:

- The student perceived the blog to be a complicated solution to communication and collaboration.
- The student perceived the blog to be different enough as compared to his/her usual workflow (i.e., his/her approach to other classes) that navigating the blog provided an extra layer of challenge to his/her approach to learning.

This student reported moderate discomfort with technology in general on the pre-survey (a response of 2 on the 5-point Likert item, with 1 being "very uncomfortable" with technology and 5 being "very comfortable" with technology). The student also indicated that collaboration is not a priority. Nonetheless, the comment elevates an oft-ignored reality of the student experience: students are enrolled in a set of classes, each with its own expectations, pedagogies, and deadlines. When researchers and practitioners attempt pedagogical innovations, we must remember that we are perturbing the student experience, and making our class "different" than the other traditional, more pedagogically mainstream (i.e., lecture-oriented) courses. This undoubtedly introduces challenges for some students.

A secondary collaboration theme emerging from the open responses is the general dislike for the "blog points" system. Students generally liked having access to the threaded homework discussions, but they almost unanimously objected to relating their blog participation to their grade. The objections centered on two issues: (i) students disliked forced participation in a shared community space, and (ii) some students attempted to make earning blog points a strategic objective rather than a learning one. We received 55 open responses along these lines, with many students citing "earning the points'' as the motivation for engaging on the blog. Examples include: ''it caused people to post meaningless things for the sole purpose of getting points'' and ''most people only used it [the blog] until they met the min. number of points''. In fact, in awarding blog points, the comments were weakly moderated by the instructor, in the sense that truly superfluous comments (''when is exam 2?'') did not count toward a student's grade. But moderating comments for quality and relevance is both too time consuming for the instructor and strongly against the ethos of a shared community space. Nonetheless, student perceptions of forced blog participation introduced a strategic undercurrent to this form of peer collaboration.

5.4.4 Prominent Theme 3: External pressures

The external pressures theme generally focused on student bandwidth, and the intensity of the engineering curriculum. Although no student specifically mentioned extra-curricular or co-curricular activities in their responses, we assume that engineering students also faced conflicting demands on their time from non-academic sources. Students wanted learning efficiency, meaning that they wanted to achieve the best result (i.e., grade) with the least amount of time and effort invested. This is human nature shaped by their educational ecosystem, and many students concluded that the extra work involved with embracing a technology-mediated pedagogy and approach to learning simply is not worth the foreseen rewards. Student comments such as ''no, it's [commenting on the blog] extra time'', or ''I don't have time to go back and search for what I need to find'', illustrated the student experience as replete with time pressures. There is no doubt that an engineering program is intense, with a rhythm and set of deadlines that are both constant and formidable. It makes sense, in retrospect, that *students might not want innovation*, especially if they perceive that innovation to (i) require more of their time, and/or (ii) have an uncertain impact on their success. These are two central tenets of a variety of diffusion theories [36], so it is not at all surprising that some students perceived these external pressures on their time to negatively impact their attitudes and experiences with the technology resources.

5.4.5 A pedagogical borderland

The pedagogical design of the course and the student comments about external pressures both characterize the ecosystem in which students learn. Specifically, this student population took many of the same classes together, simultaneously, in the same semester (and most of those classes have just one division). Students also perceive external pressures on their time that impact their adoption of technology-based study methods. The resulting student culture sought efficiency and was very collaborative. Peer support and camaraderie were generally quite strong, and study groups (self-assembled by the students) were fairly ubiquitous. *The technology innovation deployed here sets up a kind of pedagogical borderland that students had to navigate*: within their current course schedule, this class offered the *opportunity* to use a dramatically different approach to learning as compared to their more traditional classes. Some students embrace this opportunity, while others did not. Some students perceived this opportunity to be a good use of their time, while others perceived it to be ''extra'' work to engage with the technology components of the course. For instance, one student remarked: ''*Like most classes*, just working out problems from the book is the best way to study. There's no need to use technology.'' (italics ours), suggesting that the student would rather have done in this class what s/he did in all other classes to achieve success. Either way, this pedagogical borderland question deserves more research, as current literature is scant. Previous educational borderland work has often focused on the role of individual social/cultural differences within student populations [37, 38], but it appears that pedagogical borderlands have not been studied in much detail.

6. Implications for practice

This study has several important implications for engineering educators. First, these results suggest that, from the student perspective, pedagogical innovation is not an unqualified asset in the course. As such, instructors have a significant opportunity to provide coaching to students about appropriate use of all the available support resources (peers, technology resources, course blog). Our characterization of the pedagogical borderland, in the context of students' perceived external pressures, is important and helps shed new light on how students embrace new technology tools for learning. Within an intense educational ecosystem, students do not always have the time and motivation to engage with all relevant support resources or experiment with optimal combinations of resources. Studies like this one continue to illuminate student usage patterns and how they relate to student academic success.

The illusion of explanatory depth was present in our data, and we suspect that this phenomenon may be more common than most instructors would expect. The implication for practice is that instructors can coach students on the appropriate use of video solution, i.e. using the ''pause and watch'' or "solve before watching" strategies from Fig. 3. Students who engaged with the videos at higher levels of cognitive engagement seemed to reap larger benefits, and instructors can convey this advice to students.

7. Conclusions

This study considered student use of technology in an undergraduate mechanics course, with an emphasis on understanding relationships between resource usage, student attitudes and behaviors, and academic performance. We used a variety of survey-based approaches as well as gradebook data to understand patterns in academic performance, all in the context of two theoretical frameworks, the worked-example effect and the illusion of explanatory depth. Our results indicate that there are many ways to succeed and fail within the context of this resource-rich environment, and disengagement (both social and academic) seems to correlate with poor performance.

The video solutions were used by students in all grade bands, and the data suggest a worked-example effect for some students. But we believe the F students fell into the trap of the illusion of explanatory depth. They convinced themselves that they could produce the same level of performance they saw in the videos when assessed. They confused their understanding of what they had just seen for an ability to actually do it. This behavior has all the hallmarks of IOED and represents a potentially important, but negative, consequence of the worked-example effect for poor students.

Our data clearly suggest that technology uptake was affected by students' perceptions of their workload and competing demands from other courses and interests ("external pressures"). We infer that the relative advantage of using the technology is perceived to be rather low by many students, and they would prefer to simply use the same approach to studying they use in all their other courses. This pedagogical borderland idea suggests that there is a non-trivial population of students who actively do not want pedagogical innovation, especially the kind of substantial overhaul of course structure and pedagogy introduced here, especially if they perceive it to demand a substantial change to the way they approach learning. This is an important observation, because so often we focus on faculty-related barriers to adoption (time, effort) of pedagogical innovations and change strategies for engineering education. Based on this study, we suggest that some students rejected our innovation on similar time- or effort-based grounds. This student pedagogical borderland question demands more research and offers fertile ground for future work.

Acknowledgements—The authors gratefully acknowledge the help of colleagues from partner institutions who helped advise and shape this research. This material is based in part upon work supported by the National Science Foundation under Grant Number DUE-0717820. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

References

1. W. Freeman and C. Brett, Prompting authentic blogging practice in an online graduate course, *Comput. Educ.*, **59**(3), 2012, pp. 1032–1041.
2. S. Bennett, A. Bishop, B. Dalgarno, J. Waycott and G. Kennedy, Implementing Web 2.0 technologies in higher education: A collective case study, *Comput. Educ.*, **59**(2), 2012, pp. 524–534.
3. J. Laru, P. Näykki and S. Järvelä, Supporting small-group learning using multiple Web 2.0 tools: A case study in the higher education context, *Internet High. Educ.*, **15**(1), 2012, pp. 29–38.
4. J. W. S. Sim and K. F. Hew, The use of weblogs in higher education settings: A review of empirical research, *Educ. Res. Rev.*, **5**(2), 2010, pp. 151–163.
5. K. F. Hew and W. S. Cheung, Use of Web 2.0 technologies in K-12 and higher education: The search for evidence-based practice, *Educ. Res. Rev.*, **9**, 2013, pp. 47–64.
6. P. A. Tess, The role of social media in higher education classes (real and virtual)—A literature review, *Comput. Human Behav.*, **29**(5), 2013, pp. A60–A68.
7. B. K. Pursel and H. Xie, Patterns and pedagogy: Exploring student blog use in higher education, *Contemp. Educ. Technol.*, **5**(2), 2014, pp. 96–109.
8. A. Rourke and J. Sweller, The worked-example effect using ill-defined problems: Learning to recognise designers' styles, *Learn. Instr.*, **19**(2), 2009, pp. 185–199.
9. M. Ward and J. Sweller, Structuring effective worked examples, *Cogn. Instr.*, **7**(1), 1990, pp. 1–39.
10. J. Sweller, The worked example effect and human cognition, *Learn. Instr.*, **16**(2), 2006, pp. 165–169.
11. J. Sweller and G. A. Cooper, The Use of Worked Examples as a Substitute for Problem Solving in Learning Algebra, *Cogn. Instr.*, **2**(1), 1985, pp. 59–89.
12. F. Paas and T. van Gog, Optimising worked example instruction: Different ways to increase germane cognitive load, *Learn. Instr.*, **16**(2), 2006, pp. 87–91.
13. M. T. H. Chi, M. Bassok, M. W. Lewis, P. Reimann and R. Glaser, How students study and use examples in learning to solve problems, *Cogn. Sci.*, **13**, 1989, pp. 145–182.
14. A. Renkl, R. Stark, H. Gruber and H. Mandl, Learning from worked-out examples: The effects of example variability and elicited self-explanations, *Contemp. Educ. Psychol.*, **23**(1), 1998, pp. 90–108.
15. T. van Gog, F. Paas and J. J. G. van Merriënboer, Effects of process-oriented worked examples on troubleshooting transfer performance, *Learn. Instr.*, **16**(2), 2006, pp. 154–164.
16. K. J. Crippen and B. L. Earl, The impact of web-based worked examples and self-explanation on performance, problem solving, and self-efficacy, *Comput. Educ.*, **49**(3), 2007, pp. 809–821.
17. R. Moreno, When worked examples don't work: Is cognitive load theory at an Impasse?, *Learn. Instr.*, **16**(2), 2006, pp. 170–181.
18. J. Wittwer and A. Renkl, How effective are instructional explanations in example-based learning? A meta-analytic review, *Educ. Psychol. Rev.*, **22**(4), 2010, pp. 393–409.
19. S. Kalyuga, P. Ayres, P. Chandler and J. Sweller, The expertise reversal effect, *Educ. Psychol.*, **38**(1), 2003, pp. 23–31.
20. A. Renkl, R. K. Atkinson and C. S. Große, How fading worked solution steps works—A cognitive load perspective, *Instr. Sci.*, **32**(1/2), 2004, pp. 59–82.
21. R. K. Atkinson, A. Renkl and M. M. Merrill, Transitioning from studying examples to solving problems: Effects of self-

explanation prompts and fading worked-out steps, *J. Educ. Psychol.*, **95**(4), 2003, pp. 774–783.
22. R. Moreno, M. Reisslein and G. Delgoda, Toward a fundamental understanding of worked example instruction: Impact of means-ends practice, backward/forward fading, and adaptivity, *Proceedings. Front. Educ. 36th Annu. Conf.*, 2006, pp. 5–10.
23. L. Rozenblit and F. Keil, The misunderstood limits of folk science: an illusion of explanatory depth, *Cogn. Sci.*, **26**(5), 2002, pp. 521–562.
24. P. Ylikoski, The illusion of depth of understanding in science, in *Scientific Understanding: Philosophical Perspectives*, H. W. de Regt, S. Lionelli, and K. Eigner, Eds. Pittsburgh PA: University of Pittsburgh Press, 2009, pp. 100–119.
25. R. E. Mayer and R. Moreno, Nine ways to reduce cognitive load in multimedia learning, *Educ. Psychol.*, **38**(1), 2003, pp. 43–52.
26. R. E. Mayer, *Multimedia Learning*, 2nd ed. New York: Cambridge University Press, 2009.
27. D. R. Thomas, A general inductive approach for analyzing qualitative evaluation data, *Am. J. Eval.*, **27**(2), 2006, pp. 237–246.
28. QSR International Pty Ltd., *NVivo qualitative data analysis software*, 2014.
29. R Core Team, R: A language and environment for statistical computing. *R Foundation for Statistical Computing*, Vienna, Austria, 2012.
30. S. Brint and A. M. Cantwell, Portrait of the disengaged, CSHE.9.12 (June 2012). https://cshe.berkeley.edu/publications/portrait-disengaged
31. M. M. Sánchez, E. I. Rejano and Y. T. Rodríguez, Personality and academic productivity in the university student, *Soc. Behav. Personal. an Int. J.*, **29**(3), 2001, pp. 299–305.
32. M. R. Berthold, C. Borgelt, F. Hoppner and F. Klawonn, *Guide to Intelligent Data Analysis*, London: Springer-Verlag, 2010.
33. R. J. C. M. Salden, V. Aleven, R. Schwonke and A. Renkl, The expertise reversal effect and worked examples in tutored problem solving, *Instr. Sci.*, **38**(3), 2009, pp. 289–307.
34. S. A. Ambrose, M. W. Bridges, M. DiPietro, M. C. Lovett and M. K. Norman, *How Learning Works*, 1st ed. San Francisco, CA: Jossey-Bass, 2010.
35. E. J. Berger and C. M. Krousgrill, HigherEd 2.0: Web 2.0 in Higher Education, Interactive Multimedia Ioannis Deliyannis, IntechOpen, DOI: 10.5772/37505. Available from: https://www.intechopen.com/books/interactive-multimedia/highered-2-0-web-2-0-in-higher-education (March 7th 2012).
36. E. M. Rogers, *Diffusion of Innovations*, 5th ed. New York: Free Press, 2003.
37. M. M. Camacho and S. M. Lord, *The Borderlands of Education: Latinas in Engineering*, New York: Lexington Books, 2013.
38. P. Phelan, A. L. Davidson and H. T. Cao, Students' multiple worlds: Negotiating the boundaries of family, peer, and school cultures, *Anthropol. Educ. Q.*, **22**(3), 1991, pp. 224–250.

Edward Berger, PhD is an Associate Professor of Engineering Education and Mechanical Engineering at Purdue University, joining Purdue in August 2014. He has been teaching mechanics for over 20 years, and has worked extensively on the integration and assessment of specific technology interventions in mechanics classes. He was one of the co-leaders in 2013–2014 of the ASEE Virtual Community of Practice (VCP) for mechanics educators across the country. His current research focuses on student problem-solving processes and use of worked examples, change models and evidence-based teaching practices in engineering curricula, and the role of non-cognitive and affective factors in student academic outcomes and overall success.

Edward Pan, PhD currently develops tailored and customized instructor-led and web-based training to help US national security and Department of Defense customers use Amazon Web Services' cloud computing technologies. He also teaches an online course for the Instructional Technology program at the University of Virginia. His prior work includes research and development of instructional technology for STEM education in pre-K-12 and undergraduate-level engineering.