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An Evaluation of HigherEd 2.0 Technologies in Undergraduate Mechanical Engineering Courses

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ABSTRACT

Between 2006 and 2010, sophomore engineering students at four universities were exposed to technologies designed to increase their learning in undergraduate engineering courses. Our findings suggest that students at all sites found the technologies integrated into their courses useful to their learning. Video solutions received the most positive feedback and were found to be the most beneficial to the students. When used as intended, the course blog provides a discussion tool for the students allowing for asynchronous collaboration. The inclusion of technology in engineering courses has the potential to positively impact student learning and collaboration. Students find the availability of video solutions very helpful to their learning and when the course blog is used by enough students, it provides an easy way for students to receive assistance from their peers and instructors.

Keywords: evaluation, technology, Web 2.0

BACKGROUND

Introduction

As a result of the National Research Council's 1999 report Transforming Undergraduate Education is Science, Math, Engineering, and Mathematics, and other research and reports documenting the need for change in undergraduate STEM education (NSF, 2000; Reeves et al., 2004; Duderstadt, 2004; Stage and Kinzie, 2009; NSF, 2011), many institutions of higher education are making efforts to reform undergraduate STEM education. Technology plays a role as an agent of change in these reforms, often as a catalyst or an enabler of active learning (Yadav et al., 2007). As a result of these reforms some faculty have been making greater efforts to innovate instructional approaches by integrating technology into undergraduate engineering courses. Students have also indicated that the use of technology is a vital part of a high quality undergraduate engineering education. The HigherEd 2.0 (HED2) program is a pedagogical and technology framework for teaching STEM courses using modern web 2.0 tools. The long-term goals of the program are to deploy web 2.0 tools in the classroom, evaluate their effectiveness in supporting learning goals, and thereby develop and disseminate the pedagogical best practices for their use in higher education. New electronic content is being developed for undergraduate courses and to employ significant technology in the course curricula. As a part of the evaluation of HigherEd. 2.0 we sought to understand how students' attitudes about technology usage correlate with their course performance. We also expected to learn the most useful, and least useful, types of technology content for the students. Our goal was to find the combination of traditional (i.e. lecture-style) and technology-assisted instructional tools which deliver the most educational benefit to the students.

Four universities participated in the evaluation over a multi-year period. Research questions included: how does the technology impacts student learning, what are students' attitudes towards the technologies, to what degree are the technologies used by students, and does the use of technology lead to an increase in student collaboration? Across multiple semesters, each project partner used HED2 technologies in their classes, and the primary tools were blogs, podcasts, threaded discussions, various types of video solutions, and animations. Each class was conducted in a synchronous, face-to-face mode with three class meetings per week. Each course was presented in a traditional format (lectures, office hours, etc.) with the added features of HED2 to mediate learning with the technology tools. Some features of the class tools and activities:

- asynchronous communication: at all sites, some form of asynchronous communication tool was used to foster discussion among students. Blogs and discussion forums (either within or outside the course management system) were used to achieve this. Each instructor worked to make that environment student-focused and collaborative.

- asynchronous course content: each site also provided podcasts, video, animations, or other portable content for students to use asynchronously, outside of class. This content was often a recorded lecture, or a video solution.
- student generated content: each site emphasized student generated content to a different degree, although all emphasized student collaboration on the course blog/forum. One site used the course project as a platform for students to create their own video solutions to share with their peers. This student generated content (and its sharing) was very popular among the students and was also a useful pedagogical device: in order to effectively "teach" their peers, students must be confident in their understanding of the course material.

Literature Review

There is a modest but growing body of empirical research on the integration of technology into engineering education. The existing literature focuses on types of technology integration, the use of distance education or online technologies in engineering education, and the beneficial use of simulations and visualization module as add-ons to the traditional curriculum (Bruno et al., 2010; Fraser et al., 2007; Ndahi et al., 2007). With the transformative nature of technology and the need for reform in higher education, Duderstadt submits that "both young, digital-media savvy students and adult learners will likely demand a major shift in educational methods, away from passive classroom courses packaged into well-defined programs and toward interactive, collaborative learning experiences, provided when and where the student needs the knowledge and skills…as the student is evolving into an active learner and eventually a demanding consumer of educational services" (Craig, 2007). Some traditional teaching methods may be used to present interactive classroom experiences, but students will be searching for a more dynamic educational experience (Lichtenstein, 2005). However, technology as a social object will most often be viewed by university administrators and faculty through traditional philosophical lenses and the norms of pedagogical practice. New technologies are likely to be viewed as merely a more efficient means for the delivery of content to passive students in the transmission model of learning (Privateer, 1999), with no significant change in the standard lecture format (Fatt, 2003; Craig, 2007; Reeves et al., 2004). Significant change requires faculty to reexamine their pedagogical orientations, and to explore constructivist learning approaches in order for technology to act as a change agent (Yadav et al., 2007).

There is a growing body of research into the integration of basic web 2.0 technologies in the engineering educational process. Web 2.0 tools allow users to become creators rather than mere consumers of technology enhanced experiences. These tools include blogs (Pena-Shaff et al., 2005; Kim, 2008; Halic et al., 2010), wikis (Minocha and Thomas, 2007; Parker and Chao, 2007)), and video (Pinder-Grover et al., 2009) and several others (e.g., Burnley, 2009), and have potential for changing the way in which engineering education is delivered in undergraduate programs. Web 2.0 technologies, which empower individual users to easily create and share content, have a clear attraction to constructivist paradigms for education. Some researchers examining the use of technologies such as web 2.0 tools have asked how structural, interpersonal, political, and symbolic issues influence the use of web 2.0 tools in higher education (Greener, 2009). When examining the implementation of web 2.0 tools in multiple sites on undergraduate engineering instruction, one must examine how the organizational cultures of the various institutions influence the instructional climate and innovative uses of technology across sites. For instance, the culture of innovation may be more conducive at one site than at others. Faculty may be encouraged to try new technologies in instruction, or students may be more open to such innovation. Greener asserts that students are less likely to use web 2.0 tools "unless they have a clear reason for doing so" (Greener, 2009). Therefore students' understanding of the purpose of web 2.0 tools for instruction may be an important variable. Greener found that students must be explicitly encouraged to visit, contribute, and comment in order to add value to shared learning outcomes. She found that there was limited use for blogs in teaching and learning "except where reflective practice is an explicit learning outcome and learners have some familiarity with the subject". She concludes that the use of web 2.0 tools can "empower but also frighten the learner into non-participation. Structure may be needed for learners who are less self-directed or at an earlier stage in familiarity with their subject…".

Pomales-Garcia and Liu (2007) have found that undergraduate engineering students would like information presented to them in a variety of formats, such as "examples, demonstrations, stories, Web sites, notes, any form of visual display, handouts, use of group work to write papers, competitions, and oral presentations." While students like the traditional method of instruction (i.e.: using the board and overhead transparencies), they would also like to see new technologies, such as personal response systems, lecture videos, and movie clips to illustrate concepts, integrated into their classes. Students would also like to see a move away from "lecture-based courses to student-centered, application-based courses". They appreciate the use of interactive methods that "break the monotony" and when instructors teach using application instead of theory. Peer collaboration between students as they solve problems and master challenging course content allows them to obtain invaluable skills that prepare them to deal with the problems they might encounter after college. The bulk of the existing literature suggests that web 2.0 technologies may add value to engineering education, but that its deployment must be carefully considered. Students must be prepared to participate in this pedagogical approach, and the HigherEd 2.0 program and evaluation focus on these issues, as detailed in the remainder of the paper.

Bravo, Enache, Fernandez, and Simo (2010) examined the use of low-cost videos used in industrial engineering, industrial organization, and aeronautical engineering courses. The videos were intended to serve as a complement to distance classes or face-to-face instruction. They found that using videos "has a positive effect upon the students' perception regarding a better comprehension of complex concepts" (p.115). By using videos, students perceive that they are able to learn new materials more quickly and efficiently. The use of videos was also found to have a positive effect on how students viewed the learning process; most felt that using videos was more efficient and allowed them greater control over their learning as they could watch videos multiple times and in any order. Students appreciated having materials presented in a visual way. Using a variety of tools, including videos, to present information to students, teachers increased students' levels of intrinsic motivation.

CONCEPTUAL FRAMEWORK

The HigherEd.2.0 program is essentially an innovation or a technology cluster in technology-enhanced instructional methods. The Diffusion of Innovations framework (Rogers, 2003) was used as a tool to guide the conceptual development of the research and analysis. Rogers defines diffusion as: "..the process by which an innovation is communicated through certain channels over time among members of a social system" (p.5). New ideas are communicated until some collective understanding of the value of those ideas is accomplished. In this study the faculty integrating the technology were the change agents and the students were clients. Rogers suggests that innovations have characteristics such as relative advantage, compatibility, complexity, trialability and observability, all of which impact the rate of diffusion to the community. Relative advantage refers to how valuable an innovation is compared to other existing solutions. Compatibility speaks to issues of integration of content, context, need, and the prevailing values of the community. Complexity addresses the perceived ease of use and overall difficulty of the solution. Trialability refers to the ability of users to experiment with the innovation. Observability captures the visibility of the innovation within the community (Rogers, 2003, pp. 15-16). Successful technological innovations are about the reduction of ambiguity and uncertainty faced by users. Within this conceptual framework, does the use of the HED2 tools reduce the uncertainty students have about their learning and learning outcomes? Adoption of an innovation occurs in a social context, in this case the four partner universities associated with the HED2 program. The relevance to this study concerns the variation in structure presented across the university settings in which HED2 was implemented. Rogers identifies a key question that was relevant to this study: how do the perceived attributes of an innovation with in a social system, such as its relative advantage or compatibility, affect its rate of adoption?

PROJECT PARTICIPANTS AND CLASSROOM APPROACHES

Project Participants and Technology Implementation

This research study included faculty and student participants at four partner institutions: University of Virginia, Purdue University, University of Akron, and Smith College. These partnerships were established based upon the different student populations and number of students served by each institution.

- University of Virginia. The University of Virginia is a comprehensive, national, highly-selective institution whose engineering school was founded in 1836. The UVA engineering school and its 140 full-time faculty offer 10 engineering undergraduate degrees and provides a residential experience to about 2400 undergraduate students. Typical class size for sophomore mechanics is between 80–120 students. About 30% of engineering students are female and 14% of the faculty are female. The institutional culture toward technology for teaching is conservative and cautious; very few faculty in engineering are early technology adopters. Dr. Berger is the lead instructor from Virginia.
- Purdue University. Purdue University's College of Engineering was founded in 1874 and offers degree in both traditional and modern engineering disciplines. In 2004, the university established the nation's first department dedicated to engineering education. With nearly 350 faculty members and 9,000 students, the College of Engineering is consistently ranked in the top 10 by *U.S. News & World Report*. Purdue offers multiple sections of mechanics courses each semester, all with enrollments of 150-200 students. Among faculty in the mechanical engineering department, there is a willingness to adopt new instructional approaches and to innovate; many of the Mechanics instructors utilized some of the HED2 technologies even though they were not involved in the study. Dr. Krousgrill is the lead instructor from Purdue.
- Smith College. Smith College is a private liberal arts, women's school founded in 1871. Approximately 2600 undergraduates from across the nation are enrolled at Smith; the engineering program is the first accredited program for women in the nation and began enrolling students in 2000. Engineering courses are integrated with the liberal arts. There are currently ten faculty members in the engineering program. Class sizes are between 20 and 30. Dr. Mikic is the lead instructor from Smith.

- University of Akron. Founded in 1870, the University of Akron is home to about 28,000 students from 46 states and 80 countries. The College of Engineering is nearly 100 years old and offers degrees in many traditional engineering disciplines. There are 66 full-time faculty members in the College of Engineering as well as approximately 2,000 students. Akron recruits a large number of students regionally from northeast Ohio, and as a result has a significant commuter population. Dr. Quinn is the lead instructor from Akron.

While many similarities exist between the four sites, there are also some differences, both in the technology that was implemented and the evaluation data that was collected. The table below outlines the technologies used at each site during this period of data collection, as well as the courses taught under the HED2 paradigm.

Statics is a foundational sophomore-level mechanics course largely populated by students in mechanical, civil, and aerospace engineering. Strength of materials and dynamics are two follow-on courses to statics, again largely populated by mechanical, civil and aerospace engineers.

Technology Resource Definitions

The types of technology deployed in the HED2 paradigm are described below:

- video solutions ❶[1]. Video solutions are movie files in which an expert (the instructor) writes a solution to a particular problem, narrating his/her thoughts as the solution unfolds. Video solutions tap into the worked-example effect (Sweller, 2006; Schwonke et al., 2009) in which novices (the students) see expert problem solving in action. Video solutions are generally 10-15 minutes long.
- course blog/forum ❷. A course blog is simply a blog organized to deliver academic information and functionality. The HED2 paradigm has employed Wordpress, Moodle, and TikiWiki for blogging purposes.
- wiki. Course wikis allow students to edit and update course content in an asynchronous way. Wiki software tracks revisions to the content, and also tabulates user attribution. Wikipedia is the best example of a wiki.
- lecture podcast ❸. Lecture podcasts are video files that capture the lectures for a course. The lecture podcasts generally capture conceptual material, derivations, and the like, with example problems and applications covered in the video solutions. Lecture podcasts can be up to 40 minutes in length.
- animations ❹. Animations are movie files constructed using simulation software (ex.: Matlab or Working Model) to illustrate the motion of a structure or mechanism. Animations are typically short, no more than 1 minute.

1 In this section and at the end of the paper, we use symbols like ❶ to indicate hyperlinks to online examples.

Resource Type	Akron (Dyn)	Smith (SoM)	Purdue (St, Dyn)	Virginia (St, SoM)
Video solutions	√	√	√	√
Course blog/forum	√	√	√	√
Wiki	√	√		
Lecture podcast			√	√
Animations			√	
Pulse pen lecture recordings				√
Student generated content				√

Table 1: Implemented technologies by site, and courses taught under the HED2 framework for this study (key: St = statics, Dyn = dynamics, SoM = strength of materials).

- Pulse pen lecture recordings ❺. The LiveScribe Pulse pen allows users to record notes plus synchronized audio, thereby capturing live lecture audio along with hand-written notes. Pulse pen lecture recordings are the same length as the lecture, generally up to about 40 minutes long.
- student generated content. Student generated content is content in any of the above formats generated by students. This includes blog postings and comments, as well as student-made video solutions and wiki contributions.

This study focuses mainly on the usage of video solutions and the course blog/forum, because these were the common technology elements used across the participating sites.

Digital Content Creation

All digital content described here was created by the faculty involved in this study. The faculty exchanged information about hardware and software tools useful for content creation, and early on agreed to follow best practices in multimedia and information design, such as Mayer (2001) and Petterson (2002). In general, open source/free software has been used for video recording, blogs and wikis, while the usual productivity tools such as PowerPoint or Keynote were used to construct lecture materials. Certainly as faculty became more expert in the use of the technology tools and creation of the digital resources, our methods, production values, and overall quality of the products improved. We have since developed a training workshop for other faculty interested in HED2 methods.

Classroom Approaches

Faculty organized their classes and presented materials to the students in very similar fashions. All professors used a fairly traditional face-to-face class meeting to introduce new course concepts, work on example problems, and otherwise convey material to students. And each used an asynchronous blog or forum where materials could be posted and students could communicate. Video solutions were distributed by all faculty for asynchronous use by students, and three of the four professors created their own video solutions. The remaining technologies were implemented at one or two sites and will be discussed below. Dr. Krousgrill explains his usual approach:

> "I began using a tablet [PC] in class in 2000. At the start of each semester, I have the lectures put together [in hard copy] and they're available at the bookstore in town. [During face-to-face class meetings] I fill in the blanks [in the lecture notes] on the screen and the students sit and write down what I write down. I'm convinced that this is a good way to do it. [Offline] I use the blog, video solutions, and [lecture] podcasts." (interview, February 8, 2008).

Dr. Mikic expands on her approach:

> "There is an extensive Moodle site. I post assignments, links, and there's a forum where I can post things, the students can [also post questions], and they can respond to each other. Doing it this way was the easiest in terms of the structure of the campus." She maintains a "concept blog", which is a question-and-answer forum posed by her and the students. Students can respond to questions or comments posted by others. She decided "at the last-minute to have a course wiki" (interview, February 14, 2008).

She also had access to the same video solutions as Dr. Berger, though she used a different textbook in her course.

It is worth noting that with one exception–described below–no incentives were in place for students to use any of the technologies described here. Students received no course credit or other reward for either using the technology or participating in the surveys and other evaluation activities described later. The exception is the experiment at Purdue in which 3% of each student's final course grade was tied to their use of the blog to ask and answer questions of their peers. This incentive--modest though it is–does seem to have made a difference in student interest and participation in the course blog as detailed in the section on Findings.

EVALUATION DESIGN AND METHODS

Evaluation Design

A mixed-methods evaluation was designed to determine the effectiveness of different technologies in engineering classes and students' attitudes towards the technology. Quantitative data came from surveys, usage statistics, course grades, and the number of student posts to the course blog. Qualitative data included interviews with students and professors, open-ended survey questions, and classroom observations. Student interviews were held at three of the universities between May, 2007 and November, 2009. While we intended to hold focus groups and offered them to students as such, in reality, most interviews with students were conducted one-on-one. We conducted a small number of interviews with two students at a time.

Surveys were initially piloted at UVA during the Fall 2007 semester as a part of a graduate-level class on evaluation design offered through UVA's Curry School of Education. We modified them significantly after the pilot to capture more information from students. Minor adjustments were made over the next year to reflect changes in the technologies available to the students, changes in course content, and to collect additional data. Smith and UVA used identical surveys while University of Akron and Purdue created their own; Dr. Berger and Dr. Mikic both taught a statics course, so their content was similar enough that the same instrument could be used at both institutions. Akron's survey was similar to UVA's and Smith's surveys, with modifications made for course content and available technology. Purdue's surveys collected similar information, modified to fit the particular course taught, but the survey was formatted differently than at the other institutions. On all surveys, students were given open-ended questions so they could share their thoughts about the technology and explain how particular components were used by them, why they were useful, and anything else students felt was important.

Reliability has not been established for the surveys due to time and funding constraints. Reliability could be established through test-retest reliability when the same subjects are given the survey instrument in two or more administrations. The two sets of scores would be correlated for a reliability coefficient (r=0.00—1.00). Internal consistency of items would be measured using split-half reliability or using Cronbach's alpha measure. Face validity was established by having our surveys examined by multiple people as well as students when we piloted the surveys. Construct validity was established by looking at how well student responses to questions on the same topics correlated with each other (i.e. Are student responses on video solution questions highly-correlated with each other?). In all areas, the questions were highly-correlated, suggesting that we are accurately measuring students' experiences with the technologies.

At UVA and Smith, students were given three surveys over the course of the semester concerning their comfort with technology overall and in academic settings, their experiences with technology, and demographic information. Akron and Purdue administered two surveys during the semester, either omitting the pre-survey or the mid-survey. At UVA, pre-surveys were administered to a comparison group, another course section, which was taught without technology; this was not an option at the other sites due to one or more of the following: (i) all instructors/sections of the course implemented the technology to some degree, (ii) there was only one section of the course taught, and/or (iii) other instructors were unwilling to participate.

DATA ANALYSIS

Surveys from all sites were analyzed for descriptive statistics using SPSS. At each site, usage data was collected using Google Analytics, allowing us to see how many site visits occurred by student, the frequency of downloads, and the number of student posts per discussion thread. Using survey data from UVA, we ran correlations to determine whether there were any relationships between students' usage of the different technologies and any significant impacts on their course grades and other outcomes. Open-ended survey questions were coded for themes using NVivo (QSR International, 2011). Student and faculty interviews were audio recorded and summaries were written after interviews were conducted. Interview data were analyzed for themes using the constant comparative method (Glaser and Strauss, 1967).

FINDINGS

All data is taken from survey responses and student interviews conducted during between 2008 and 2009, as well as data collected from instructors over that same period.

Overall, student response to the technologies was positive at all sites. While all of the technologies received positive evaluations, students perceived the video solutions as being more useful to their understanding of course topics. Students at all sites accessed the course blog, but Purdue students found it to be more useful than their peers at the other institutions.

Student Populations and Participation

At each site, survey participation was very strong. All students in each participating class were recruited to take the surveys; participation was voluntary and did not impact their grades. Surveys

Data Type	University of Akron	Purdue University	Smith College	University of Virginia
Student surveys	Fall 2008	Spring 2008	Fall 2007	Fall 2007 (pilot)
	Spring 2009	Fall 2008	Spring 2008	Spring 2008
	Fall 2009	Spring 2009	Fall 2009	Fall 2008
	Spring 2010	Fall 2009	Spring 2010	Spring 2009
		Spring 2010		Fall 2009
				Spring 2010
Student interviews	Fall 2009	Spring 2009		Fall 2007
				Spring 2008
Faculty interviews	Spring 2008	Spring 2008	Spring 2008	Spring 2008
	Fall 2008	Fall 2008	Fall 2009	Fall 2008
	Spring 2009	Spring 2009	Spring 2010	Spring 2009
	Fall 2009	Fall 2009		Fall 2009
	Spring 2010	Spring 2010		Spring 2010

Table 2: Data collection by site and type of data.

were given at the end of a class session and the majority of students in attendance participated in the surveys. At UVa, 72 students took the pre-survey, 81 students completed the mid survey, and 88 completed post surveys. 44 students from Akron took the mid survey and 43 took the post survey. 84 students from Purdue completed post surveys. At Smith, 24 students took the pre survey, 23 took the mid survey, and 22 took the post surveys. Students were recruited for interviews via email and by an evaluator during class sessions. All students were invited to participate in interviews as well, though no student interviews were conducted at Smith. In all, five students from UVA, nine from Akron, and eleven students from Purdue were interviewed.

Instructor Time

Regardless of any educational outcomes we might show, an appropriate question is: "How long does this take?" During the first semester of full implementation of HED2 across all four partner sites (Spring 2008), we collected time records from each instructor to examine how they spent their time on different phases of course preparation and delivery. Time data was self-reported by the instructors using a project management software suited for this purpose. This data does not include in-class lecturing time itself (which would add about 45 hours to the total time for each instructor). The results for the four partner instructors, and the overall time averages are shown in Figure 1. All four instructors

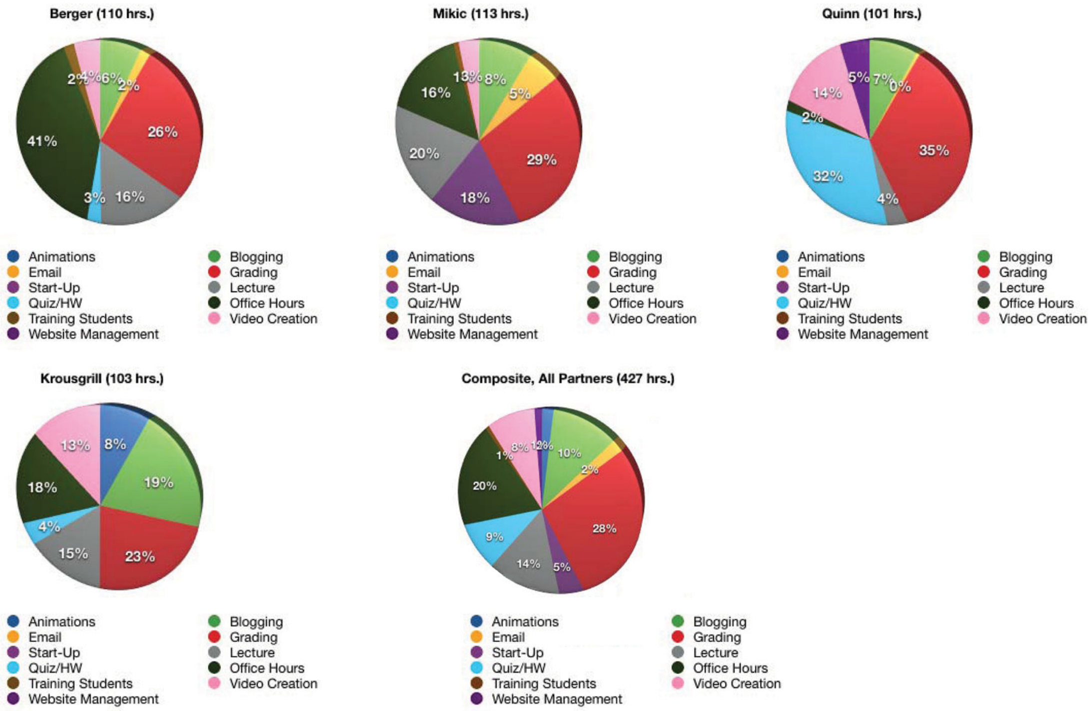

Figure 1. Faculty time logs for class-related activities, Spring 2008.

spent roughly the same amount of time on their courses, but there is some variation in how that time is spent. For instance, Dr. Berger and Dr. Krousgrill had a significant amount of archived course content (podcasts, videos, etc.) from previous semesters, so in Spring 2008 they spent a relatively small amount of time on media content creation. The newest partner, Dr. Mikic, spent significant time on start-up and generally becoming conversant in some of the technologies. Dr. Quinn spent quite a lot of time creating new course content for his spring course, (though not learning HED2 tools and strategies, with which he was already conversant), and this is reflected in his time spent on homework solution generation and video creation. We expect the margin of error in the time record to be on the order of 6 to 10 hours over the entire semester (less than 10% of the total recorded time). Several encouraging results are clear; when implementing the HED2 paradigm:

- Class-related activity is dominated by the usual instructional requirements: lecture preparation, grading, office hours, quiz and homework creation (about 71% of the composite time for all partners).

- Start-up costs are significant, but not outlandish; Dr. Mikic spent roughly 20 hours getting up the technology curve and becoming adept at the usage of the web 2.0 tools she used.
- Blogging is an elastic property that can be a large or small time commitment, depending upon how "present" the instructor is in the blog discussions; Dr. Krousgrill spent over one hour per week managing and interacting with students on the blog, while Dr. Berger spent about 0.5 hour per week.
- Digital content creation is another elastic property, and the time spent depends upon the availability of archived digital assets suitable for re-use; in Spring 2008, Dr. Berger had over 100 digital assets available for use in his class, so he did not need to create many more.

On balance, for faculty members already conversant with the technology and pedagogical approaches of HED2, and with a reasonable archive of digital material, we expect the time required to deliver a class this way is 10-15% more than would be required to deliver a traditional course.

Usage and Usefulness of Course Blogs/Forums.

Analytics data. We collected analytics data on blog/forum usage, and across all sites students average roughly five site visits per week during the academic semester. For a class of 100 students, this equates to over 7,000 site visits for the semester. As a practical matter, these five visits per week are most likely concentrated around times when new information will be useful for students, i.e. before homework assignments are due or tests are scheduled. But this data does suggest that students actively check for updates, new materials and assignments, and new information posted in comment threads. All students from each site report accessing the blog, largely because there is no other source to which they can turn to obtain class assignments. Very few students use the available RSS feed for the blog. Students report that they generally check the blog at a convenient time and location; for example at UVA, about 84% of students typically accessed the blog while alone. The majority of students across all sites report that the blog is easy to use.

Usefulness of Course Blogs/Forums. Student perceptions of the value and usefulness of the blog vary by site. At Virginia, Akron, and Smith (which offered no incentives for student participation and collaboration on the blog), students generally felt the blog was an adequate mechanism by which instructors could distribute course information, but they were less enthusiastic about the student-to-student collaboration mediated by the blog. Students at these three locations largely cited their lack of need for that form of online collaboration. "Classes are sufficient," commented one Virginia student. "I get the homework and that's it. If I have questions, I generally just call a friend in the class. I never really think to look on the blog," said another. "The study materials and exam review posts are very helpful, but I don't feel that discussing homework through blog comments is useful," wrote a student. One Smith student remarked, "I think that face to face meetings and working with other students is much more effective than the electronic material, especially since I am not the best writer and usually cannot express myself effectively through writing." Generally, students at these three sites saw the potential for asynchronous discussion on the blog to positively impact their performance in the class, but they lamented the general lack of participation: "Sometimes you can't figure out why you are getting a problem wrong. Checking to see if other students have had the same issue and seeing how they resolved it could be helpful," commented a student.

Purdue's blog implementation is essentially the same as at the other sites, but the incentive structure is different. Purdue's students received up to 3% of their total class grade for participation in discussions on the blog, with a graduated point scale accounting for the level of activity of each individual student. Student reports about the incentive structure were mixed. While many students say that being required to use the blog exposed them to the value of the technologies, others disliked that participation was required. One says, "I liked the blog, I did not like the associated points with posting though." At least some of the students seem to understand the motivation behind requiring participation. One student explains, "Giving points for blog participation is, unfortunately, often the only way that fellow students will help others on the blog. Truthfully, I usually only visited the blog when I had questions, not when I was looking to help others." Another comments, "Assigning a portion of the course grade to blog posting made me look at the blog. Once I was there I wanted to post on the blog." This final comment suggests that for at least some students, requiring participation provides both intrinsic and extrinsic motivation.

About 70% of Purdue students visited the course blog at least once a week, and about 75% actively participated in online discussions about course material. Students report that comments made by their peers were usually or occasionally helpful to them. "[It's] very helpful. [A] great way to have homework help and study, no matter where you may be since it is online," commented one student. Another said, "[It] helped immensely...would be great if every class did this. It also gives the professor some insight [as] to whether students understand the material or if it needs to be covered more." "This website is invaluable to learning the material. I might have never grasped the material if this site did not exist," said another student. Many students at Purdue feel the blog contributed to their success in the course. One student explains how it was beneficial for him, saying, "[I] use the blog as a private tutor. I am slow at learning by nature, so I have to review this thoroughly and even have it explained many times. Often it is hard to make office hours but the blog solved this. I watched all the videos pertaining to concepts, blog is reason I am doing so well in class. Thanks!"

Accessibility of Information and Ease of Collaboration. University of Akron has a larger commuter population than the other institutions in the study and a few students expressed that the blog structure makes materials more easily available to them when they cannot be on campus. "What's on there [the blog] is a lot easier to get to and you know, I live, like, a 30 minute drive away so I can't really come up here and ask questions," comments one student.

One reason students do not utilize the blog for collaboration is because they believe it is easier to collaborate in person. This seems to be due to three factors: 1) some students struggle to articulate their questions in written form, 2) some enjoy the social element of collaborating face-to-face, and 3) some do not trust their classmates to respond to questions quickly or accurately. Students said that some of the assigned problems are difficult to explain in words and it is easier to "just show someone and ask them". Many said they live with or have other classes with peers from their engineering class, so they may not have the need for online collaboration. Two interviewees specifically mentioned socializing while they study as a positive. Another perceived drawback to online collaboration seems to be their reluctance to rely on their classmates to give a timely response. One student from Akron mentioned leaving the discussion forums up on his computer screen as he was doing homework in case something was posted that might be useful.

Students have found that collaboration on the blog can make their schoolwork less stressful. One commented: "The blog is the thing I use the most, specifically the posts about the solutions to the homework problems. I think that really helps me out because last year in statics when I got stuck on a homework problem I'd just end up being really frustrated and this year if I get stuck on a homework problem, I can go to the blog and see what other people are thinking and see if I did something wrong, where my thought processes are going wrong. That improves my motivation to do the homework and makes me more interested in doing it because if I get stuck, I know I'm not just going to be on my own."

Blog Summary. These results indicate that students see the potential value of blog-based online collaboration. But in the absence of extrinsic motivation (such as a part of their course grade at Purdue), students are unlikely to invest the time and effort required to make the blog a vibrant learning community. Students from Akron, Virginia, and Smith all echoed similar sentiments, captured by this Smith student's comment: "It's only helpful (the technology components) if everyone uses it." And getting a critical mass of participants apparently requires incentives, as we explore later in the Discussion.

Video Solutions

Video solutions were made available to students at all sites via the course blog. The following results illustrate student usage patterns and perceptions of usefulness from Virginia students, as measured by surveys and interviews. About 82% of students reported that they had downloaded between one and five video solutions. The rest did not download any. However, more students reported watching video solutions than downloading them, indicating that the videos may have been shared among students in the class. Only about 6% of students watched none of the video solutions; about 28% watched between one and five; about 33% watched between six and ten; about 10% watched 11-15; 24% watched more than 15 video solutions. The majority of students watch the video solutions for exam preparation and they tend to report being alone when they view them.

Students from UVa were asked to rate the usefulness of the video solutions for specific content areas during their statics and strength of materials courses (fall and spring semesters). Some students reported not watching the video solutions, yet rated them anyway; this may skew the results in the following section. Overall, students perceived the video solutions to be of high usefulness for all content areas. Content areas in Table 3 are presented in chronological order and include data from Dr. Berger's strength of materials course.

UVA students wrote several positive comments about the video solutions. "Very useful, well put together, and easy to follow," commented one student. "They're super effective," wrote another. One student offered a minor criticism, writing that, "Video solutions are extremely helpful to visual learners like myself. I wish there would be more posted to the blog because it was a hassle to go to the publisher's website [where the videos were hosted]." A few students mentioned using the video solutions specifically as resources for exams. "I breeze through them before tests," said one student.

At Purdue, the majority of students viewed the video solutions at least once a week. The video solutions are found to be highly helpful to students for both homework assistance and exam preparation. A few students had suggestions for improving the video solutions such as, "[It] would be nice to have .pdf solutions along with the video for quick referral and an aid for studying for exams."

Course Topic	High (%)	Medium (%)	Low (%)
Statics review	54.5	21.2	24.2
stress, strain, & material properties	58.8	20.6	20.6
Axial loading	67.6	14.7	17.6
Torsion	77.8	11.1	11.1
Bending	75.0	11.1	13.9
Transverse shear	70.6	17.6	11.8
Combined loading	75.8	12.1	12.1
Mohr's circle/stress transformations	75.0	9.4	15.6

Table 3: Perceived student usefulness of video solutions from University of Virginia.

Another said, "[It] would be nice to have the written out solutions with explanations as well as the videos for times when you cannot view it with sound or technical difficulties. Also, there could be an indicator at the bottom of video playback that could indicate which step of the problem it is in for easy jumping."

Overall, Purdue students found the video solutions to be valuable to their learning of the course materials. "Very helpful for exam studying, and forced me to solve the rest [of the problems]. Of course, this ultimately led to a higher exam score," said one student. Another commented, "Helpful, good explanations, [I] would not get grade I am going to have without [the] videos." Students also appreciated the ability to access the materials at their convenience. One said, "Amazing, because you can access them anytime anywhere and refresh your memory on certain concepts."

At Akron, most students report that they viewed at least some of the video solutions posted to the course website. Forty percent have viewed between five and ten video solutions and about 35% have viewed more than 10 video solutions. Students report being alone when they watch the video solutions and most watch them while doing homework.

Students at Smith College used the same video solutions as those at UVA and accessed them through the textbook publisher's website. They also had access to video review problems which were given with homework problems. The majority of students viewed between one and five of the suggested video review problems while only 24% viewed any of the video solutions. The video review problems were most often used by students while they did their homework, though about a third of them used them for test review. Nearly all students viewed the video solutions while they were alone. Even though UVA (Table 3) and Smith (Table 4) utilized the same video solutions in courses, the data from the institutions differs due to differences in course content and organization at each site. Also, Table 3 includes data from two semesters; Dr. Mikic was on sabbatical during the

Course Topic	High (%)	Medium (%)	Low (%)
Shear stress & strain, allowable stress, safety factors	11	72	17
Axial stress and strain, material properties	21	63	16
Torsion	7	73	20
Bending	27	53	20
Transverse shear	0	73	27
Stress transformation equations	0	64	36

Table 4: Perceived student usefulness of video solutions from Smith College.

second year of the study, so we do not have that data available from both semesters for her classes for inclusion in Table 4.

Student comments on the video solutions were mixed. One Smith student wrote, "The video review problems are extremely helpful. The approaches to solving problems are great. It's like having mini lectures that can be rewound or fast-forwarded as needed. A couple of them I have viewed more than once." Another said, "I don't feel the need to use them because they move too slowly." One student appreciated the ability to access the information at all hours, saying, "Video solutions are great because I can 'work' through problems with someone and see an example at 1 a.m. or when I couldn't make it to office hours."

Lecture Podcasts

Overall, across the two sites at which lecture podcasts were available, students rated the lecture podcasts to be of medium to low usefulness (Table 5). It is important to say that these lecture podcasts generally contain conceptual material and derivations, with very little in the way of example problems and direct application of the concepts (applications examples are handled in the video solutions). Data from the UVA midpoint survey found that 80% of students had accessed zero to four podcasts at that point in the semester. When asked why they did not watch more podcasts, most students responded that they do not watch the podcasts because they either have no need to or no time to. "I attended the majority of the lectures, so it wasn't necessary," wrote one student. Others felt that getting the materials in a different format was more useful for them. "Applying concepts is what is most useful," said one student, "so watching/reading [video] solutions is much more helpful than getting concept material [from the lectures] again." Yet the majority of students perceived the lecture podcasts to be of at least medium usefulness to them. Material from early in the semester (which is conceptually easier) was judged to be of relatively low usefulness, while late-semester lecture material such as Mohr's circle and stress transformations (which is considered to be conceptually more difficult) were given the highest usefulness rating with 31% of students finding them of high usefulness. Content areas in the table are presented in chronological order and include data from Dr. Berger's Strength of Materials courses.

Many students said that they did not view the lecture podcasts, yet few students gave reasons. One explained that he did not use the podcasts because: "They are too lengthy to sit down and watch." Another student echoed this sentiment, saying that the lecture podcasts are "too long, but I don't know how to fix that problem". Some students seemed to view the lecture podcasts as a way to catch up on lectures they missed. One student commented, "I only watched one lecture podcast, when I had to miss class, but it was helpful."

Course Topic	High (%)	Medium (%)	Low (%)
statics review	6.9	55.2	37.9
stress, strain, & material properties	6.9	55.2	37.9
axial loading	6.9	55.2	37.9
torsion	17.2	48.3	34.5
bending	17.2	51.7	31.0
transverse shear	20.7	48.3	31.0
combined loading	27.6	41.4	31.0
Mohr's circle/stress transformations	31.0	34.5	34.5

Table 5: Perceived student usefulness of lecture podcasts from UVA.

Collaboration and Social Construction of Knowledge

Both surveys and interviews, across all sites, support the notion that students like to engage in social learning, and that the technology components of HED2 can promote social learning. But once again, differences can be observed, perhaps related to the local culture on campus, in how students actually collaborate.

At UVA and Smith, collaboration among students is a key feature of student life; 92% of UVA students and 100% of Smith students indicate that working with classmates was a priority for them, and it was beneficial to their learning. Both of these campuses are residential experiences, and Smith's small program in particular encourages a tight sense of community among their female student population. At Akron, which has a higher percentage of commuting students, fewer (less than 60%) students indicated they collaborated actively with other students in the course.

Interviews with students revealed more details about the nature of their collaboration with other students, and in particular their attitudes toward online vs. face-to-face collaboration. In general at Akron, UVA, and Smith, students value collaboration but favor face-to-face interactions. Students often cited factors such as convenience (they live with roommates who are also in the class), or apprehension about writing in a public forum. A student at Akron explains, "I like to get together with people and work out the problems instead of … [pause] Just 'cuz you're working on it at the same time and you don't have to type out stuff. 'Cuz half the time you're pointing out, 'What about this part and this part?'"

In addition, it appears that some students were uncomfortable with the online form of collaboration because they had not participated in it before--this is the technology diffusion question. A

Purdue student explains some difficulties in using the technology, saying, “[I] found it difficult to add attachments to my blog posts, but then again I have never used a blog before this, so I may just be bad at things like that.” A UVA student who had Dr. Berger for two semesters comments, “I was really resistant to it [the technology] last semester, but I now see the value and efficiency of it. There’s definitely an adjustment period to get comfortable though.” Another UVA student writes, “I didn’t have Dr. Berger for Statics last semester, so the blog and related tools forced me to change the way I use technology in support of learning. There was a slight learning curve/adjustment period at the beginning, but now I’m a pretty big fan of the blog and all of that.” These comments illustrate that once students become comfortable with the technology, they find it beneficial to their learning.

Finally, many students at Akron, UVA, and Smith cited the general lack of student participation in online collaboration as the key factor limiting its effectiveness and attractiveness. A student from Akron says, “It’s easier to find someone in person than hopefully catch them online.”

Students at Purdue, however, indicated in interviews their high degree of satisfaction with, and enthusiasm for, online collaboration. This is largely related to the large and active user community, as well as the timeliness of the information provided. One student commented: “The discussions on the blog were very beneficial to view … I was promptly helped by both Prof. Krousgrill and other students.” And another student appreciated the online collaboration tools as one more option for communication: “Seems effective for users who like to interact with others by adding one more easy and time-efficient way.”

Summary of Collaboration. This research emphasizes the value students place on collaboration, and supports the notion that the course blog can foster an environment in which sharing is safe, positive, open, and (perhaps most importantly) accessible to all. While the course blog does provide a flexible structure to host this collaboration, we see again that technology uptake requires time, coaching/advocacy on the part of the instructor, and a critical mass of users to engage in that form of communication. Our experience with these online collaborative environments is once again usefully viewed through a diffusion of innovation (Rogers, 2003) framework, presented below.

Impact of Technology on Student Outcomes

There were few significant correlations between students’ final grades and their usage of the technology. There was a significant relationship ($\alpha = .01$) between the number of lecture podcasts downloaded and student grades; the more podcasts downloaded, the higher the students’ grades. The relationship between final grades and students’ experiences creating materials for their final project was also significant ($\alpha = .01$).

Significant correlations ($\alpha = .01$) were found between the percentage of study time spent using technology and students’ perceptions of the usefulness of video solutions for content areas. The greater percentage of time spent using the technology, the greater perceived use it had for students. However, there was no significant correlation between the percentage of time spent using the course technology and final grades.

DISCUSSION

Video Solutions Add Value

This study indicates that video solutions hold value for students, and students embrace them and include them in their regular study habits. The value of video solutions can largely be understood in the context of the worked-example effect (Sweller, 2006), which essentially states that, for novice students, acquisition of problem-solving skills comes at a lighter cognitive load when studying worked examples (e.g., the video solutions) than when solving problems themselves. The work of Sweller and others is very persuasive here (e.g., Schwonke et al., 2009), and reinforces the idea that novice learners need expert guidance to solve complex problems. The video solutions provide exactly that, in a format that is asynchronous, easy to access, easy to use, portable, and an exact replayable copy of the expert perspective. While it would be tempting to argue that the video solutions might replace the types of recitation sessions often held by teaching assistants, we have not conducted the type of study that would provide evidence of such value. Indeed, losing the interpersonal connection with a TA might be deleterious and our goal here was certainly not to establish a preference for using the videos to improve (say) fiscal efficiency. However, one could speculate that in schools or universities without the resources to provide TAs, the use of the video solutions might assist with student learning.

Blogging Adds Value, Given a Sufficient Number of Users

We have seen that students gradually understand and adopt the blog as a course resource for distribution of course materials, regardless of their initial level of comfort with the blog. In addition, students have reported that the blog's interactive and community-building features (i.e., threaded discussions) could be useful tools to support their learning. And indeed, students at all sites saw this potential benefit, but only the students at Purdue achieved a large enough user community to realize significant benefits of peer-to-peer interactions (and their participation in the blog discussion was incentivized). This observation is consistent with the general conclusions in the literature about the blogging and the sense of community. For instance, Halic et al. (2010) (in a study in which all students were required to author both posts and comments on a course blog) conclude that perceived learning from a course blog correlates positively with a student's sense of community engendered on the blog, as measured using survey instruments that probe each variable. Moreover, the literature suggests that in educational contexts, students are motivated to participate in message boards and blogs by the feedback they expect from their peers; in the absence of such participatory feedback, students are less likely to engage in online communication. Indeed, Rogers (2003) argues that communications channels are an important part of innovation adoption. He states that interpersonal communication channels are effective diffusion mechanisms that influence adoption by the broader community. To Rogers, these "near-peers" influence the community and the overall potential for adoption or rejection of an innovation. So our results echo those recently reported in the literature, but also dramatically illustrate the needs for incentives/requirements to promote student participation.

Impact of Technology

The statistically significant relationship between students' final grades and the degree to which they had positive experiences while creating their final projects is likely because students who did well in the course overall were more likely to have an enjoyable experience creating a final project and feel that they gained a greater knowledge of course concepts via the project since they already had a reasonable understanding of the materials. Students who did not perform as well in the course may have experienced more difficulties with a final project that required a high level of mastery of materials and find it less enjoyable as a result.

One of the strongest claims we could make about whether the technology impacts student understanding utilizes questions from the Fundamentals of Engineering (FE) exam, an eight-hour test which is taken for licensure in engineering (http://www.ncees.org/exams/fundamentals/). Questions similar to those on the FE exam were placed on the final exam in both the treatment class (Dr. Berger's) and a comparison class. While there were a few statistically significant differences between the two classes in terms of comfort with technology, comparing students' scores on the FE-style question would allow us to determine if the students in the treatment class scored better than those in the comparison group and if the technology was a factor in the increased scores. This is an area we need to explore with further data analysis.

Technology Adoption Takes Time

The classical theory of diffusion of technological innovations (Rogers, 2003) directly applied to this research program. In brief, Rogers' theory states that "diffusion" is the means by which an innovation is communicated through specific mechanisms over time to a social community. Here, the innovation is the use of web 2.0 technologies, the communication means is the integration of the technologies into mechanics classes, the diffusion time is measured in weeks throughout a semester, and the social community is the students in class. We have seen different rates of technology adoption by faculty—rates that seem to reflect the culture of each institution—and a wide range of enthusiasm and adoption from students.

From the beginning of this work, we hypothesized that the HED2 paradigm would positively impact learning, and that students and other faculty would readily adopt this approach. However, in retrospect, it is not particularly surprising that there are several critical steps to making HED 2 a widely-adopted innovation:

- <u>Make the digital resources easy to access and use</u>. There is no doubt that the blog provides a strong backbone for course management and communication. Easy navigation, platform independence, and ubiquitous access make the blog an excellent choice. Similarly, the video and podcasts are distributed in platform-independent file formats, with modest file size, and are available anytime, anywhere. Video solutions are easy to download, easy to manage, and easy to watch.
- <u>Demonstrate usage</u>. While not discussed previously in the paper, we have found that integrating use of the technologies in class–and demonstrating to students how to access and use the blog, videos, etc.–eases student concerns about their ability to use the technology.
- <u>Initially, incentivize participation</u>. Perhaps the most significant lesson we have learned is that incentives matter to students. Recall that Purdue was the only campus to reward students for blog participation (3% of their final grade), and their participation rate on the blog–students collaborating and helping each other far-outpaced the other sites. Students at Virginia, Akron, and Smith consistently stated that the blog could be useful, but lamented the general lack of participation. Social media like blogs rely upon a critical mass of users to make them truly useful, and we have learned that incentivizing participation early on speed the rate of technology adoption and usage. Moreover, as learned at Purdue, once students understand the power of asynchronous collaboration on the blog, they continue to use it actively–even after they have fulfilled their obligations to obtain the full 3% on their final grade.

While UVa, Akron, and Smith students were encouraged to utilize the available technology, it was not mandatory and they did not receive credit towards their course grade for their participation. In contrast, Purdue students had 3% of their course grade ties to usage of the technology. As Greener (2009) found, students must be explicitly encouraged to visit, contribute, and comment in order to add value to shared learning outcomes (p. 187). In the case of undergraduate engineering students, our findings suggest that students need initial extrinsic motivation to access the materials available to them through the course blog. Purdue students stated that they would likely have not contributed to the course blog as much as they did if “we didn’t have to” to get points towards their grade. Yet every student interviewed said that once they had used the materials and seen how useful they were, they would use them without needing to receive points.

Culture of Innovation

Rogers (2003) reminds us that in the diffusions of innovations, the adoption occurs within a social system that is:

> ...a set of interrelated units that are engaged in joint problem solving to accomplish a common goal. The system has a structure, defined as the patterned arrangements of the units in the system, which give stability and regularity to individual behavior in a system. The social and communications structure of a system facilitates or impedes the diffusion of innovations in the system. Norms are the established behavior patterns for the members of a social system.

Rogers also asserts there are various innovation factors related to the organization such as the individual leader characteristics (positive or negative attitude toward change), and factors related to the characteristics of the organization's structure such as the level of centralization, or the level of complexity. The level of formalization within the organization, the level of interconnectedness or the degree to which the units in the system are linked by interpersonal networks, the degree of organizational slack and the size of the organization.

There were clear differences in the level and speed of adoption of these new technologies for both students and faculty. We cannot help but wonder how the local culture of innovation impacted adoption. Faculty time commitments are typically large, and discretionary time to develop new expertise is typically limited. So it is somewhat surprising that several faculty at Purdue actively deployed the technologies in their classrooms, based upon their own initiative, outside the scope of the HED2 program. Their voluntary efforts are conspicuous, because no such technology transfer to other faculty occurred at any other site. Perhaps not coincidentally, students at Purdue were incredibly willing to participate in focus group interviews, perhaps revealing a more active culture of innovation and experimentation at Purdue than at the other campuses. For example at UVA, very few students volunteered for focus group interviews and even fewer faculty engaged with these technologies in their own classes; perhaps this is a reflection of an institutional conservatism that resists innovation and experimentation. A more thorough characterization of each institution's culture, and how that culture promotes or inhibits innovation, is certainly in order and may shed light on the diffusion rate for these innovations.

INDEX OF EMBEDDED HYPERLINKS

- ❶ video solution example: http://advances.asee.org/vol03/issue01/media/05-media01.cfm
- ❷ video blog description: http://advances.asee.org/vol03/issue01/media/05-media02.cfm
- ❸ lecture podcast example: http://advances.asee.org/vol03/issue01/media/05-media03.cfm
- ❹ animation example: http://people.virginia.edu/~ejb9z/Media/Sample_media/impact_problems/
- ❺ Pulse pen solution example: http://people.virginia.edu/~ejb9z/Media/Sample_media/pulse_pen/

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