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HigherEd 2.0: Web 2.0 in Higher Education

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1. Introduction

The web 2.0 era, which began in the mid-2000's, has ushered in unprecedented opportunities for individuals to author and share content, to amplify their voice, and to generally share information in a rapid and platform-independent way. Throughout the past five years, both blogging and video have become completely mainstream as a result of powerful browser-based platforms such as Wordpress (blogging) and YouTube (video sharing). Bandwidth has become largely ubiquitous, with high-speed wireless connections available in a huge variety of environments. And now, with the surging usage of smartphones and other mobile devices, users can capture video, upload it to YouTube, and share it via a link on their blog or a Twitter update, all from their phone and all within just a few minutes. In the future, the names of the tools may change, but the pervasiveness of powerful authoring and sharing tools will continue to be a primary part of the fabric of communication and social interactions.

The education community has viewed these new tools the way it usually views technology–with much optimism but also with deep skepticism. The history of technology integration in education is replete with strong successes, but also many solutions that failed to achieve widespread adoption or make significant gains in student learning outcomes. The social media tools of the web 2.0 era are often greeted with special skepticism; perhaps this is because of the perception that the user-as-author model for content creation empowers everyone to have a voice, regardless of their authenticity as experts. There is certainly an element of web 2.0 technologies that feeds on a kind of modern narcissism (Grossman, 2006), but it also enables crowdsourcing the energy, ideas, talent, and (often free) labor from a global user community (cf. Wikipedia). And it also challenges the deeply-held beliefs of faculty members and the long-standing traditions of higher education instruction: the instructor is the expert who acts as a knowledge gatekeeper, giving students access to information in a controlled way. Web 2.0 shatters that structure, with learners empowered like never before to access *and create* information, share it with their peers, comment on it, refute it, and generally view it through many different lenses. The expert perspective of the faculty member is no longer the only voice in the classroom.

The HigherEd 2.0 program seeks to harness both the web 2.0 technologies and the energy of the learners in the service of creating a modern learning experience. The program is motivated by the basic recognition that with so many web 2.0 tools to choose from, and so many ways to deploy those tools, educators would be well served by a set of best practices, validated using assessment data, guiding their use of multimedia tools. The consequences of *ad hoc* usage of any tool can be important for learners; tools that are difficult to use, inconvenient, deployed inconsistently/haphazardly, without clear purpose, or that provide no competitive advantage versus other tools can all impose significant cognitive load on the learner and impact his/her learning (see also Section 3). In addition, *ad hoc* usage also undermines widespread adoption, as described in Section 6. The HigherEd 2.0 program is therefore dedicated to deploying web 2.0-based technology interventions in real higher education classrooms, evaluating their usage and effectiveness, and constructing a pedagogical framework that can be used by the education community.

To clearly explain the HigherEd 2.0 paradigm and its implementation, this chapter is organized as follows. In Section 2 we introduce the technologies used in our classrooms, the key elements of which are blogs and videos. In Section 3, we use a cognitive load theory framework (CLT) to connect these multimedia tools to instruction, and explain why carefully-considered usage of these tools makes for sound pedagogy. In Section 4, we discuss our findings on best practices for using web 2.0 tools in higher education. Section 4.1 describes best practices in multimedia production, while Section 4.2 presents more detail about the course blog and its impact as a critical organizing framework for course material, communication, and collaboration. Section 5 introduces the notion of student-generated content (SGC) in which students are empowered to create and share their own educational materials with their peers. Section 6 gives an overview of the evaluation of the HigherEd 2.0 program, including usage data, student survey results, interviews, and connection to learning outcomes. We also introduce a diffusion of innovation framework to understand adoption patterns for HigherEd 2.0 technologies. Finally in Section 7 we summarize our findings and explain the future directions of the research.

2. Multimedia types and uses in engineering education

Multimedia-assisted instruction refers to usage of a combination of media including audio, text, images and video in the delivery of instructional material. The effectiveness of multimedia instruction is supported by the modality principle from educational cognitive theory which, in summary, states that concepts presented *both* visually *and* verbally are remembered better than when stated *either* visually *or* verbally. This principle is employed even in traditional lecture delivery where the student learning can be enhanced by listening to the lecturer present visual materials as compared to reading the same material in the course textbook. Recent web 2.0 technological advances have allowed for the economical production of an expanded base of possible multimedia materials. Critical integration of these multimedia components into course delivery can effectively tap into learning gains from the visual and auditory channels of input.

The philosophy within the HigherEd 2.0 program has been to develop multimedia material using consumer-grade, web 2.0 approaches rather than on the use of enterprise-level synchronous production tools such as Elluminate. Web 2.0 tools were chosen on the basis of ease of use and costs. The tools require little training for the instructors, virtually do-it-yourself in terms of the level of their complexity of use. If used for recording live lecture delivery, the controls are simple enough that the lecturer can comfortably run the recording without the need for additional support personnel. The hardware and software required for production of the multimedia material is typically either available within the academic department or is of sufficiently low cost that they can be easily purchased for use. The portability of the equipment allows for recording at virtually any location, such as in office and/or home environments.

The required web 2.0 multimedia production tools include: tablet input device, inking software and screen/audio capture software. The tablet input device can be either a tablet PC or a drawing/graphics tablet connected to a desktop/laptop computer. Tablet PC's are more common; however, drawing tablets generally provide a larger format for higher quality writing and drawing. There are wide variety of choices of software for inking, with the Microsoft products of Journal and OneNote being the most widely accessible. The recording software must be able to record both the spoken word and handwriting from the screen. Camtasia is a widely-used application available for both Windows and Mac OS computers that allows for a variety of output formats and video compression. A high-quality USB microphone is recommended for capturing the best audio. Basic post-production audio and video editing can be done with applications such as QuickTime Pro; more advanced editing requires applications such as Final Cut Pro. A low-cost, yet high-quality, alternative to the above set of production tools is the smartpen that allows simultaneous recording of speaking and of writing with a digital pen on digital paper. The small size of the pen is considerably more portable than a tablet PC and allows for "anywhere recording" of videos. This approach is, however, more limited in that the recording of handwriting overlaid on prepared notes is not currently possible and the post-production editing of the resulting Flash video can be complicated.

Platform independence of playback is an important consideration in the design of multimedia material. Students should be able to access these learning materials through desktop/laptop computers and mobile computing platforms such as smartphones and tablet devices. Although this chapter does not focus on the deep technical details of the multimedia material, it is important to mention that file format and video compression choices need to be considered. Most HigherEd 2.0 multimedia components have been produced using either H.264 video compression or Flash technologies based on the current omnipresence of such players on the internet. Although smartphones are currently screen size- and resolution-limited, we believe that the delivery of course materials on mobile and/or tablet devices will be less encumbered in years to come.

We acknowledge that production tools such as Elluminate have the advantage of synchronous delivery and, with that, the ability for live interaction with the instructor. However, students often do not take advantage of this interactivity feature, possibly due to a reluctance to interrupt or due to fears that their fellow students will be critical of the questions asked. Within the framework of HigherEd 2.0, the multimedia components are tightly integrated within the course blog; this integration allows for students to ask questions on the blog with the real time of their viewing of the material.

The HigherEd 2.0 program has focused on the development of the following five multimedia components: lecture videos, video solutions, animations, simulations and case studies. The details of these are provided in the following.

2.1 Lecture videos

Generally speaking, a traditional lecture for an engineering course can be divided into three parts: a lecture of fundamental concepts, the working out of solutions for examples related to the lecture topic, and a review discussion. The lecture portion typically covers mathematical details that are relevant to overall conceptual understanding, and provides subtle cues to the students for developing their problem-solving abilities. The opportunity for asynchronous playback of lectures can benefit students across the entire spectrum of academic abilities and time schedules, as well as support different pedagogical styles used by instructors. From a student perspective, even skilled note-takers are often unable to capture all of the relevant points of the lecture. Playback will allow students to "fill in the blanks" on missing sections of their lecture notes. Students unable to attend class due to illness or travel are afforded the opportunity to catch up on a missed class. From a pedagogical perspective, some contemporary ideas on instruction are based on the implementation of a "flip" order of course material presentation (Yale et al., 2009). With this approach, a recorded lecture component is delivered online for viewing by the students prior to the class period. The lecture recording covers the fundamental concepts as well as specific cues to the students that connect to the "live" portion of class, during which directed problem solving sessions and lecture-based quizzes are conducted.

Within HigherEd 2.0 courses, videos of the lecture component ❶[1] of the class are produced, either from a live lecture delivery or from an in-office recording session. The instructor starts either with prepared notes (in PowerPoint or PDF format) or with a blank file on a pen tablet computer. Synchronized voice and screen capture recordings are produced and compressed using appropriate video compression algorithms. When recording live lectures, the instructor is able to easily pause recording on a real time basis to eliminate any segment of the class period not desired on the final recording (such as when addressing administrative course details or example solving portions of the class). For either a live lecture recording or an in-office recording, the lecture module video can be as short as 15-20 minutes and as long as 40-50 minutes, in length. The final lecture recording is then posted for viewing on the course blog.

2.2 Video solutions

During a typical engineering lecture class period, a number of examples related to the class period topic are presented to the students. The instructional goals of these examples are the reinforcement of fundamental course concepts and the direction of students in the development of the problem-solving strategies. Most engineering textbooks contain worked-out example solutions, with the amount of solution detail and number of examples dictated by publishing limitations. Similarly, both the amount of solution detail and number of examples worked out during the lecture period are limited, in this case, by time restrictions.

For courses served by the HigherEd 2.0 program, solution videos ❷ are produced for lecture examples using the voice/screen capture process described above for lecture video recording.

[1] Throughout the text, we use symbols such as ❶ to indicate the presence of a hyperlink to external media; these links and their URLs are summarized in Section 8.

The examples chosen are staged in level of complexity ranging from the simple application of a single concept to multi-concept engineering problems. These solution videos are able to provide deeper insights on problem-solving strategies than that afforded by the space-limited textbook and time-limited in-lecture solutions. The audio component of the recordings allows the instructor to provide significantly more insight on the nuances of the individual examples than is possible otherwise with written words alone. And, of course, asynchronous playback allows students to replay portions of the solutions on difficult concepts on multiple devices.

2.3 Animations

The inability to visualize motion is often a major obstacle to learning in engineering courses, particularly in the area of mechanical sciences. This obstacle manifests itself in two ways. Firstly, if a student is not able to determine how a system moves, he/she will be unable to dissect the system into its relevant components for analysis. Secondly, without well-developed visualization skills, the student will be unable to relate the mathematics of analysis to the physics of the motion (does the final quantitative answer make qualitative sense?). The use of static images in traditional instructional delivery is often insufficient for describing motion since the image presents the geometry of the system at a single snapshot in time.

Computer software such as Working Model (and, in a more limited way, Matlab and Mathematica) can be used for the construction of visually-displayed mathematical models of mechanical systems. These models can be used for showing both the physical motion and the mathematical description of the motion. Through the use of this software, mathematical models for a large number of problems for courses covered in the HigherEd 2.0 program have been developed. Videos are produced for simulations using multiple sets of input parameters. Learning modules ❸ are produced in which these animation videos are integrated with spatially contiguous text directing the students through an examination of the motion displayed. A focus is given to both a discussion of the overall system motion and to the qualitative connection to the mathematics to the motion.

2.4 Simulations

The animation video modules described above represent an application of linear multimedia. The active content of the material progresses without navigational control by the student viewing the video. This presentation and companion textual discussion is limited by the parameters chosen by the designer, and the modules do not allow for nonlinear “what if" investigations by the students. An alternate instructional design could include the replacement of the animations in the modules by direct connections to the Working Model simulation package, where the students would be able to control the system parameters through the package’s graphical user interface. An alternative involves the instructor distributing Matlab or Mathematica files that students can then edit and run on their own machines. In either case, software licensing may become an issue, raising both the cost and complexity of solutions like this. These issues certainly speak in favor of browser-based simulations, or even simulations/applications for mobile devices. These solutions generally require a different skillset than most faculty possess, and are therefore uncommon.

2.5 Case studies

The multimedia components described up to this point have been used together in HigherEd 2.0 courses in leading instruction from specific concepts (lecture video) through their application to specific problems (solution videos, animations and simulations). In contrast, case studies are a means for leading a longitudinal study from a specific response back to an understanding its underlying concept. The intended outcome of the study is for the student to gain a sharpened understanding of how the fundamental concept led to the observed response and how this concept can be applied to the understanding of other responses. Case study modules ❹ have been developed for HigherEd 2.0 courses. These modules integrate any number of the above types of multimedia components, including a review of fundamental concepts of a lecture video, example solution videos showing how the concept leads to the observed response, and animations/simulations demonstrating how choices of system parameters lead to this and other types of response.

3. Multimedia pedagogy

The HigherEd 2.0 program employs three main elements that leverage different bodies of literature on student learning: the course blog, video solutions, and student-generated content. The course blog, as an information delivery and communication/collaboration platform, supports students' feeling of inclusiveness and community, both of which are known to support student learning (Halic et al., 2010). Video solutions and other multimedia assets leverage the worked-example effect (Sweller, 2006), which has been repeatedly shown to outperform problem-based learning especially for novices. Student-generated content taps into the scholarship on self-efficacy and constructivism, and cultivates a collaborative learning community among faculty and students. As described in the following sections, the HigherEd 2.0 program and approach is well grounded in the pedagogical literature.

The HigherEd 2.0 program can be grounded in Cognitive Load Theory (CLT) (Sweller et al., 2011), which posits that humans have a finite capacity to process information. In a learning environment, this means that learners are continuously processing new information in *working memory* while simultaneously drawing on their own experiences and prior knowledge from *long-term memory*, in the service of *schema acquisition and automation*. A schema is simply a framework, held in long-term memory, that learners use to understand problems and their solutions–schemas integrate complex information (both new information and a learner's prior knowledge) into a formal approach to cognitive tasks. The ease with which learners acquire or automate schemas (i.e., integrate their new knowledge with their prior knowledge) depends very closely on the cognitive load associated with those tasks and, of course, the complexity of those tasks. CLT breaks cognitive load into three basic categories:

- external cognitive load (ECL): the cognitive load associated with the way information is presented
- intrinsic cognitive load (ICL): the cognitive load related to the inherent complexity of the task or problem
- germane cognitive load (GCL): the cognitive load associated with the acquisition or automation of schemas, i.e., the load associated with actually learning new things

CLT suggests that an individual's cognitive load during learning is simply the sum of ECL, ICL, and GCL. Learning is compromised when this total cognitive load exceeds an individual's cognitive capacity ("cognitive overload"), especially when the elements of the topic to be learned are "interactive" or highly coupled (Sweller, 2010). Moreover, learning is maximized–especially for challenging problems with high ICL–when instructional designers present information clearly with a minimum of extraneous or confusing information (they *minimize* ECL), therefore maximizing the available GCL used to support schema construction. Novice learners spend a great deal of time on schema *acquisition*–learning how to approach problems, which tools and strategies are useful, and which tasks (and in what order) must be executed. Schema acquisition can be very demanding, and therefore instructional approaches must focus on optimizing the learner's cognitive load so that his/her finite cognitive resources can focus on only the most important elements of schema acquisition. On the other hand, more advanced learners spend more time on schema *automation*–the process of making "automatic" the execution of certain solution features. Automation of specific tasks and processes lowers the cognitive load associated with those tasks, and enables learners to focus their cognitive resources on learning other aspects of a problem. Experts tend to have fully automated schemas and therefore solve problems in their domain of expertise with very little cognitive load.

3.1 The course blog and a blended environment

The HigherEd 2.0 paradigm promotes a blended environment, with some instruction taking place in a traditional classroom setting but a great deal of asynchronous interaction using a course blog as well. Controlling the extraneous cognitive load in either environment is obviously critical to fostering learning, and in this section we focus on the course blog as an instructional asset and communication platform. Research on blogging in higher education has largely focused on its comparison to a more traditional course management system (CMS) in terms of performance, functionality (Huang, Huang & Yu, 2011), and ease of use; a key dividing line between CMS and blog platforms is the extent to which they foster *transfer of information* versus *authentic communication* (Hamuy & Galaz, 2009). CMS platforms tend to function as virtual filing cabinets, while blogs can promote conversation and social elements such as tags. In the late 2000's, blogging became completely mainstream in political, social, and other domains, and blog use in higher education is emerging rapidly[2] and changing the course management landscape (as CMS platforms continue to add "social" features such as blogs and threaded discussions).

Scholarship on best practices in blogging has developed over the past 10 years, over which time user comfort levels with blogs have changed dramatically. Controlled trials that evaluate blogging as a learning tool typically take long enough to complete that over the observation period, attitudes about and usage patterns of blogs can change significantly; what we thought was salient about educational blogging in 2004 may no longer be relevant [see (Sim & Hew, 2010) for a review]. Nonetheless, there does seem to be several enduring features of blogging that impact its success as a learning environment, all of which can be recast in a CLT framework. There are specific elements of blogging in the context we present here that either explicitly or implicitly impact ECL:

[2] Even five years ago, we had to explain to students what a blog was, why it was being used in our class, and what value it might add. Very little explanation is required today.

- presentation: the presentation, organization, grammar, quality of writing, etc. impact perceptions about usefulness of a blog [Kerawalla et al. (2009), Kim (2008), Lambert et al. (2009), Huang, Huang, Liu & Tsai (2011)]; difficult-to-use blogs or poorly-written blog entries impose a higher ECL on the learner
- connectedness: a sense of isolation/community can inhibit/promote learning, especially for learners in a purely distance (instead of blended) format [Halic et al. (2010), Garrison & Aykol (2009), Kerawalla et al. (2008)]; anxiety about participation in the public forum of a blog, or a lack of feeling of connectedness to the community of learners, induces a higher ECL on the learner
- facilitation: facilitation by an instructor is important to foster focused discussion on the blog [Garrison & Aykol (2009), Hernández-Serrano (2011)]; less-focused discussions make it harder for the learner to identify relevant information, and impose a higher ECL on the learner

The preponderance of the recent scholarship supports the notion that blogging can be a valuable pedagogical tool, and as discussed in Section 4.2, the course blog forms the critical backbone of each HigherEd 2.0 course.

3.2 Fading and the worked-example effect

The HigherEd 2.0 paradigm makes extensive use of video solutions, as well as other multimedia assets, in promoting the learning goals of the course. Indeed, the video solutions form one half of an example-problem doublet, in which students can watch video solutions in preparation for completing homework or practice problems. This doublet arrangement–watching a worked-out example before trying problems on their own–has been repeatedly shown in the CLT literature to promote schema acquisition. Video solutions fall into the category of “example-based learning”, in which students study worked-out examples in an effort to learn new problem solving strategies. Homework and other practice problem solving constitute “problem-based learning”, in which students actually do problems in order to learn new problem solving strategies. And CLT provides a unifying framework to understand how and why both examples and problems support student learning.

First consider the cognitive load associated with example-based learning using a video solution designed according to the best practices of multimedia production (see also Section 4). While watching the video, students do not need to try to listen and write at the same time (as they do when, for example, taking lecture notes), nor do they have to think about the steps involved in the solution. These two features of the worked-out example (plus its instructional design) reduce the cognitive load associated with presentation of the material (ECL) and with the complexity of the problem (ICL), so that the learner’s working memory can focus almost entirely on the germane cognitive load and the acquisition of a problem-solving schema. From this careful and deliberate deconstruction of problem solving into a clear worked-out example, students acquire problem-solving schemas with a minimum of cognitive effort. This is the essence of the *worked-example effect*: students acquire problem-solving schemas by watching experts solve problems. The worked-example effect has been repeatedly shown to be especially potent for novice learners whose prior knowledge is low and whose problem-solving schemas are not at all well formed in long-term memory (Moreno, 2006). The worked-example effect promotes *schema acquisition*.

Problem-based learning takes a different approach, summarized as: students learn how to solve problems by solving problems. But the scholarship on CLT has shown that for novices, solving problems as a means of constructing problem-solving schemas can, paradoxically, inhibit learning. Typically, novices take a problem solving approach that is goal-oriented or "means-ends", meaning that novices consider the current status of their solution, compare it to the goal of the solution, and use an ad-hoc (perhaps even trial-and-error) approach to moving their solution closer to the goal for the problem. This is not uncommon among novices, who have neither the prior knowledge nor the robust problem-solving schemas committed to long-term memory. As such, the means-ends analysis itself imposes a heavy cognitive load (ICL) on the learner, who must think about the problem, the goal, and all the potential steps that would advance their solution toward the goal (Sweller, 1988). Sweller and colleagues have also shown, however, that for more experienced problem solvers, solving problems is more beneficial than worked-out examples (Kalyuga et al., 2001). Sweller contends that solving problems promotes *schema automation*.

Learners undergo a natural transition from novices, when studying worked-out examples promotes schema acquisition, to experienced problem solvers, when actually solving problems promotes schema automation (Renkl & Atkinson, 2003). And HigherEd 2.0 is a program designed for use in actual instructional environments–semester-long courses during which, presumably, novice problem solvers will evolve into experienced problem solvers. A strategy which helps navigate this novice-to-experienced transition using worked examples is called *fading* (Moreno et al., 2006). Fading strategies typically ask students to study a partially-worked-out example, and execute the correct steps to complete the solution. In *backward fading*, learners must complete a solution whose initial steps have been worked out. In *forward fading*, learners must complete the initial steps of a solution whose later stages have been worked out. Fading has reliably proven to be a good novice-to-experienced transition strategy in a variety of specific cognitive tasks, including electrical circuits (Moreno et al., 2006) and financial analysis (Renkl & Atkinson, 2003).

3.3 Student-generated content

The learning impacts of HigherEd 2.0 student-generated content can be understood in a social constructivist framework, mediated by technology. The "social" elements of the theory emphasize student peer-to-peer interactions, peer teaching, and the general role of each student in the co-creation and sharing of knowledge. Rooted in Vygotsky's theories (Vygotsky, 1978) of learning originally developed for elementary school children, social constructivism indicates two basic contributions to learning. The first is that the essence of constructivist learning is student collaboration and sharing, that students can learn from each other, and that the "teacher" often learns more than the "student". Annis (1983) presents an interesting experiment in peer tutoring: three groups of students study material. One group studies in anticipation of taking a test, the second group studies in anticipation of teaching other students the material, and the third group studies in anticipation of teaching other students and then actually teaches others. The "read and teach" group performed better than either of the other groups in learning gains, including on higher-order cognitive tasks. Similar results have been reported by Benware & Deci (1984), Wagner & Gansemer-Topf (2005), Roscoe & Chi (2007), and Gregory et al. (2011). This body of research has recently spawned the notion of *communal constructivism* (Holmes et al., 2001), which stresses the collaborative and intentional construction of knowledge by both teacher and student for the benefit of the community at large. McLoughlin & Lee (2008) provide an extended review of new and emerging enhanced constructivist pedagogies.

The second positive impact of student-generated contact and peer-to-peer collaboration relates to student confidence and self-efficacy, both of which positively correlate to achievement (Multon et al., 1991). Blogs and wikis represent two user-friendly platforms on which students can create and share knowledge and educational resources. The sense of community engendered in such online environments enhances student confidence in addition to their technical skills (Wheeler et al., 2008). The classroom environment becomes collaborative instead of adversarial, and competition among students is supplanted by collective effort in support of learning outcomes (Halic et al., 2010). These and other positive effects of constructivist learning can be stimulated using HigherEd 2.0 strategies, as illustrated in Section 5.

3.4 Multimedia in higher education

Design guidelines for multimedia learning materials are readily available in the literature [e.g. Mayer (2009), Schnotz (2005) and other chapters in the *Cambridge Handbook*], and we refer the reader to those sources for greater depth of coverage. The brief summary we present here focuses on design principles for multimedia learning that serve to optimize cognitive load on the learner. The CLT framework provides rich granularity to the discussion of multimedia authoring, with various "effects" and "principles" serving specific purposes in managing the cognitive load. For example, the *spatial contiguity* principle states that learning is improved when descriptive words are placed spatially closer to related parts of figures. The *modality effect* suggests that descriptions should be presented as narrations rather than as written words. The *coherence effect* directly targets ECL and suggests that extraneous information and material should be removed from multimedia learning materials. These and other effects–temporal contiguity, redundancy, and so on–are well documented and supported by theoretical and empirical research. The HigherEd 2.0 system employs these guidelines as cognitive load reduction strategies [cf. Mayer & Moreno (2003)] in real higher education settings.

4. HigherEd 2.0 best practices

The HigherEd 2.0 program has focused primarily on two types of web 2.0 components for undergraduate engineering education: instructional multimedia and the course blog. The multimedia components include: lecture videos, video solutions, animations, simulations and case studies. The design of these media has been closely aligned with pedagogical principles that foster the best possible student learning. The course blog serves a dual purpose of providing student-to-student interaction through discussion threads and of providing a critical organization framework for the delivery of media and other instructional material. Based upon our extensive experience in deploying web 2.0 technologies in higher education settings, as well as the scholarship about multimedia learning, we have developed the best practices described in the following sections.

4.1 Best practices in the design and production of multimedia

The design and production of multimedia components should fall in the latter stages of the overall instructional design process. The learning objectives of the course topic should shape the overall flow of a multimedia-assisted module. A designer is encouraged to pay attention to the instructional congruence among the learning objective, the instructional method, the media and the learner. Generally speaking, the focus for the module should remain narrow. Attempting to accomplish too much with a single topic can lead to cognitive overload in the learner, sending out an unclear instructional message. Cost and technological complexities should be a consideration in choosing the appropriate media; however, the web 2.0 technologies employed in the HigherEd 2.0 program are generally inexpensive and relatively easy to use. The following provides a description of the connection between the method and media for the media components used in HigherEd 2.0. These descriptions consider the different options on how the related instructional media are developed and produced.

4.1.1 Lecture videos

One of the first considerations in the production of lecture videos is the value of live lecture recording vs. that of an in-office lecture recording. A live lecture environment will be most familiar to the student and will likely be the most engaging when considering the body language, facial expressions and personality of the lecturer. The best live lecture production includes classroom video along with audio and screen capture. The classroom video adds considerable cost and complexity to the production in terms of manpower required for video recording and the post-production process of superimposing the classroom and screen capture videos onto a single frame. Without classroom video, unintended audio irregularities (such as extraneous noises and periods of silence) become distracting to the viewer. The in-office lecture recording model allows for a more polished presentation. Audio quality is more easily controlled. Rehearsing the lecture prior to recording and re-recording segments of the lecture both lead to a better final product. Most screen capture recording software allows for “talking head" video insets of the instructor to be included in the lecture recording. The value of these insets throughout the lecture should be considered [Sorden (2005), Nielsen (2005)]. Do they add communicational value? Is the space on the screen better used by written lecture notes? An alternative is to include a short, full-screen video of the instructor at the beginning and/or end of the lecture when the lecture topics are introduced and/or summarized.

4.1.2 Video solutions

The HigherEd 2.0 program has shown the strength of the worked-example on learning in foundational engineering courses. A solution video and a textbook worked-example share the same pedagogical deconstruction of a problem into its relevant parts and the delineation of problem-solving strategies. The power of the video solution lies in the modality of an audio description with text and graphics. The design and production of solution videos should always remained focused on optimizing the positive impact of this modality. Simply reading what is being written on the screen adds little value. Use the audio component to amplify the problem-solving strategy. Explain nuances and provide context of a problem-solving step to others. Provide considerable detail in the handwritten portion of the video. Although some students may only listen and watch, many will be taking notes; complete written thoughts are important for this group of students. Write legibly. Use color creatively for graphical emphasis, but do so selectively. Rehearsal prior to recording is highly recommended; however, working without a script is good practice in that in leads to a fresher presentation.

4.1.3 Animations and simulations

Animations and simulations allow students to observe the dynamic and visual consequences of mathematical concepts. Animations are motion recordings whose parameters and initial conditions are set by the designer, whereas in simulations the user has control over selected input parameters and initial conditions. Learning objectives totally dictate the design of these components. If the goal is to demonstrate global motion of a system, the animation/simulation should allow visualization of the entire system. Alternately, the learning objective might be focused on a qualitative assessment of analytical results, in which case the visualization needs to focus on graphical representation of those results. Unlike lecture videos and video solutions, animations and simulations are not standalone media components; they require contextual connection to analysis. The best practice is to embed them within a focused learning module. In this module, the problem is concisely described with text and images/videos followed by a summary of analytical results (possibly along with a solution video). The critical component of the module is discussion directed at one aspect of the solution alongside the animation/simulation. Multiple animations (or a single simulation module allowing student interactivity) are required for “what if" discussions. Spatial contiguity principles should be followed in the page layout for the module allowing for students to simultaneously observe related components on the page without scrolling or links to other pages.

4.1.4 Case studies

The instructional method for case studies is based on the illustration of a concept through an example. The case study leads from a specific situation back to the general principle, generally the reverse of the other tools discussed here. The case study is more difficult to design from a pedagogical standpoint. From a media standpoint, its design employs the components described above. The layout of a case study module shares similarities with those used with animations and simulations. The problem is introduced using text and graphics/videos and is connected to relevant lecture and solution videos by textual discussion that lays out the thought process in arriving at the general underlying concept. At the end, the student is allowed to study the relationship of the original example problem to the underlying mathematics through animation and/or simulation components. Spatial contiguity principles dictate the layout the module in the same way as for the animation and simulation modules described earlier.

Table 1 summarizes a set of best practices for multimedia production as learned from the HigherEd 2.0 program.

4.2 Best practices in course blog design

The course blog serves two primary functions. First, the discussion thread of the blog is a social platform that encourages interaction and sharing between students. Second, the

1. *Synchronize all temporal input*: Spoken narration should be synchronized with on-screen action.
2. *Eliminate extraneous information*: Do not include extra information that is not relevant to the problem, because this increases the ECL for the learner.
3. *Keep it short*: Longer videos can contain too much information for students to assimilate. Our experience is that 15 minutes is about right.
4. *Use consistent color schemes, formatting, and overall aesthetics*: Take care to use color and other visual elements consistently both *within and across* videos, so that students can easily recognize the meaning of specific formatting conventions. written descriptions using color ❺; e.g., the red equation accompanies the red annotations and text on a figure.
5. *Keep it current*: Deploy videos when students need them, and make sure students are aware when useful new videos become available.
6. *Don't write a script, but do rehearse*: Use Mayer's personalization principle; use conversational language to describe your approach.
7. *Compress*: Large videos (>100 MB in size) may present problems for students with slow connections at home. Compress your videos using a modern standard, such as H.264. Good-quality videos can be produced at a size of 1 MB/minute for tablet-based videos.
8. *Spend the time and money to polish your hardware and software setup*: Creating your videos on a substandard setup increases the cognitive load on the instructor! Make sure your setup makes it easy for you to produce and distribute your videos.
9. *Distribute video in a format and manner that encourages use*: Use a standard, platform-independent video format, such as Quicktime, so that students can access and play videos on a wide range of devices.
10. *Critique your productions on a regular basis*: Revise (or eliminate) material that has been determined to be ineffective for learning. There is no need to keep media that students do not use.

Table 1. Best practices in video production and distribution.

blog serves as an organizing framework for course material, particularly for the multimedia material for the course. The function and form of each dictates the design and implementation of a successful course blog. This video ❻ describes a typical HigherEd 2.0 course blog, its features, and how it is used and organized.

The discussion threads of the blog should facilitate an uninhibited exchange of ideas among the students leading to cooperative learning. This exchange could mimic that of a small group of students sitting around a table discussing a homework problem for the course. In this small group, the students offer up their opinions without concern of judgement from their peers. Not all opinions are correct; however, after a period of time the group settles on a consensus opinion. The blog discussion can follow this model; however, the blog group includes the entire class, and the participants can remain anonymous via careful choice of their blog username[3]. With the larger group on the blog, the accuracy of the group consensus is improved greatly. The course instructor is able to monitor the discussion but should intervene only when necessary to keep the student bloggers on track. By silently observing the blog discussion, the instructor has gained considerable insight on the depth of the students' understanding. Difficult concepts, as learned from the blog, can become part of a lecture discussion in the next class period.

Issues of learner-control vs. instructor-control need to be considered when maintaining the blog during the course term. We have observed that if the initiation of discussion threads is left up to the students, multiple posts related to the same issue (such as the solution of a homework problem) can appear on the blog. This produces many disconnected threads with few comments per thread. The continuity and interaction of discussion is lost in this way. We recommend that the course instructor add blog posts to initiate discussion threads on anticipated issues of interest to the students (homework problems, exam reviews, etc.). These posts can be used to set the tone and focus of discussion by the blogging students. Students should also be allowed blog permissions to author posts, permitting them to start discussion threads on topics not anticipated by the instructor.

Students are more likely to be engaged in course discussion if the blog is spatially connected with the course multimedia content. To accomplish this, course material is accessed through links to content pages on the blog. With this layout, students do not need to leave the blog as they review course material. Blog comments and posts can be added directly from the course content pages.

Note that blog discussion threads are temporally organized, generally in reverse chronological order. Course material, on the other hand, is best organized topically. This difference in form for the two blog functions should be kept in mind when setting the organizational standards for the blog. One should not insert topical material within the temporally-organized discussion thread. Furthermore, the blog designer should make extensive usage of tags on both discussion threads and content pages to assist the students in locating relevant material.

Table 2 summarizes a set of best practices for blogging as learned from the HigherEd 2.0 program.

5. Student Generated Content (SGC)

The web 2.0 era not only empowers instructors to author multimedia learning materials for their students; it also offer unprecedented empowerment to students to create learning materials for each other. The pedagogical rationale for integrating students into the production and sharing of learning material is simple: in order for students to effectively "teach" their peers, they must develop a high level of expertise in the subject. This peer element of instruction has existed in a variety of forms and with many names essentially since the dawn of time, and it has consistently been shown to add value to learning (Hsiao et al., 2010). But the advent of powerful new tools always injects new excitement and pedagogical opportunities. Web 2.0 tools specialize in authorship and collaboration, two critical elements that empower participants to easily create materials and share them with a large audience.

[3] Of course, the instructor–as blog administrator–will know the user's identity, but other participants on the blog may not.

1. *Don't assume anything*: On the first day of class, (and several times thereafter) discuss the role of the course blog. Students will better understand your expectation throughout the course.
2. *Limit your involvement in discussion threads*: Let students discuss the issues on their own. Your involvement will likely curtail participation.
3. *Reward blog participation*: Giving minimal credit for participation lets the students know that you consider blog participation to be important.
4. *Control who can add to the discussion thread*: Make it easy for students to comments; however, require a login and act as moderator to prevent outside contributors.
5. *Create leads on discussion threads*: You want to keep the students focused on relevant issues. Start out the discussion with a hint.
6. *Learn from discussion threads*: Watch the discussion threads to identify student difficulties or misconceptions that can be addressed in the next class meeting.
7. *Use good organization, and keep it all in one place*: Use tags and categories to help students locate material. Know your 'pages' from your 'posts'. Have all course content on the same blog. A student who leaves the blog to an external link might not return.
8. *Allow user anonymity*: Allow students to choose a user name that protects their identity, if they wish. The instructor should be the blog administrator, and will therefore know users' identities. But allowing anonymity can reduce anxiety associated with participation in a public forum.
9. *Keep it current*: An out-of-date blog signals to the students that you are not interested in them using the blog.
10. *No funny stuff*: Do not post irrelevant material on the blog. Discourage students from doing so.

Table 2. Best practices in blogging.

The HigherEd 2.0 program leverages student creativity and ambition to amplify the voice of the learners. While we have employed a wide range of SGC formats and strategies [including wikis and podcasting assignments (Berger, 2007), (Berger, 2009)], we focus here on the two most productive forms of SGC: blogging and construction of worked examples.

5.1 The course blog and social constructivism

The course blog (the technical details of which were presented in Sec. 4.2) presents a simple, direct avenue for student authoring and sharing. Student participation in blog-based, asynchronous discussion–in a public forum–supports the collective construction of understanding celebrated in *social constructivist* theories of learning. Social constructivism emphasizes that learning is: (i) a process that requires social interactions and is time-evolving; (ii) contextual and reliant on the culture of the learning community; and (iii) personalized, with students influencing the direction and format of the learning. The blog is an inherently social learning tool that encourages discussion, collaboration, and sharing.

In the parlance of CLT, the blog promotes schema acquisition via social means. Students share ideas about how to approach problems, discuss the details and meanings of specific facets of problems, and collectively construct an understanding of how to approach the problems. A typical example of this process is shown in Figure 1, in which students use the nested commenting features of the course blog to asynchronously collaborate on homework solutions. Each individual student brings his/her prior knowledge and schema (under construction) to the discussion, and the outcome can be considered as a transcript of schema construction by these individuals.

(student 1) Reply:
April 20th, 2009 at 10:51 am
I think you must have made a sign error somewhere bc you should end up with (m + (3/2)m) in front of your x_dotdot term. With this I was able to get
omega_n = 15 rad/s
zeta = 0.4
omega_d = 13.74 rad.s (is this correct units?)

(student 2) Reply:
April 20th, 2009 at 2:02 pm
Yes, it has to be radians/s

April 20, 2009 at 10:22 am

(student 3) says:
I got all the same answers as (student 1), also did part (d) and found that the response is x(t) = e^(-15t) * (0.29sin(13.75t))

(student 4) Reply:
April 21st, 2009 at 12:05 am
don't forget that in the exponent of e, zeta is multiplied by w_n

(student 5) Reply:
April 21st, 2009 at 2:52pm
So with zeta = 0.4, the actual answer is x(t) = e^(-6t)*(0.29sin(13.75t))

(student 6) Reply:
April 22nd, 2009 at 12:34pm
I get all the same answer for Part A thru C, but im having a lot of trouble with part D. Im not really sure how to construct my x(t) equation. Any pointers?

April 20th, 2009 at 2:07 pm

(student 7) says:
I got the same answers as (student 1). My EOM was
x_dotdot + (2c/5m)x_dot + (2k/5m)x = 0
and then
x(t) = (e^(-6t)) * [.29 sin(13.75t)]
April 20, 2009 at 2:21 pm

(student 8) says:
I used the sum of the forces in the x-dir of the disk and then sum of the moments about the center of the disk. Solved the moments for friction and then plugged it back in the x-dir equation. I then did sum of the forces in the x-dir of the block and solved for the reaction force at O and plugged it into the x-dir of the disk and simplified for the EOM.
I got
EOM: x_dotdot + (2c/5m)x_dot + (2k/5m)x = 0
wn = 15 rad/s
April 20, 2009 at 2:30 pm

Fig. 1. A sample threaded discussion on the course blog.

5.2 Student worked examples

Another component of student-generated content with HigherEd 2.0 is student creation of worked examples. Throughout the course, students consume instructor-created worked examples as they learn key concepts and problem-solving strategies. Once students have progressed along the novice-to-experienced transition to a sufficient degree, they are in a position to create (video) worked examples for their peers. Video creation is only possible now, with the rise of web 2.0, because the intrinsic cognitive load related to authoring in the video production environment is almost negligible. Students create videos seamlessly, because the authoring tools are so powerful and user friendly that they essentially fade into the background[4]; students are free to focus entirely on the germane cognitive load of constructing worked-out examples for their peers. Throughout their experience in a HigherEd 2.0 course, student have encountered a large number of instructor-generated worked examples, each one a specific example of how to effectively construct multimedia learning materials (Mayer, 2009). Despite their lack of formal training in multimedia pedagogy, students generally create quality solutions consistent with multimedia learning principles, and challenge themselves to truly master the problem solving approach. This example ❼ of a hand-written, student-generated video solution uses a white board, multiple colors, live narration, and a hand-held video.

It might seem counterintuitive that the HigherEd 2.0 approach promotes construction and sharing of worked-out examples by students–students who have already substantially moved beyond the novice phase of problem solving. The worked-example effect is known to be most powerful with novice learners, so why would student-generated content be valuable in this form? The answer lies in the pedagogy; the worked-out solution assignment is not designed to explicitly benefit the learning community (although it certainly can do that by providing solutions to problems with which students might struggle). Rather, students construct these learning materials as an exercise of *schema automation*, therefore accelerating their transition to experts. Indeed, as instructors already know, teaching any material to novices requires a high level of expertise in the subject matter (cf. Section 3.3). Using the familiar Bloom's Taxonomy (Krathwohl, 2002) language, when students create authoritative solutions for problems, they focus on *creation* and *evaluation*, the two highest cognitive domains in the taxonomy. Students build a solution that they perceive to be the "best" solution to a given problem, explain the solution clearly using available tools and techniques, and present it using digital tools so that others can learn from their example.

6. Evaluation methods and results

6.1 Evaluation overview

The HigherEd 2.0 program uses a mixed-methods evaluation that emphasizes both quantitative and qualitative data. Because these strategies are deployed in real higher education courses across an entire semester, the study cannot be conducted in the well-controlled environments characteristic of much of the educational psychology or cognitive science literature. Instead, we have constructed the evaluation with a combination of usage statistics, survey data, gradebook information, and student and faculty interviews. The results presented here are a subset of the broader evaluation data, more of which is included in Orange et al. (2011). Because the HigherEd 2.0 paradigm rests upon such a

[4] It is worth noting that when we started developing the HigherEd 2.0 paradigm in 2006, we had to provide training to students on video production using tools like GarageBand. Now, in 2011, no such training is required, and students often simply use their mobile phone cameras to capture video solutions written on paper or a white board.

strong pedagogical foundation (Section 3), for the rest of this section we focus on high-level conclusions about student participation, satisfaction with the learning environment, and overall rates of adoption of the technologies for learning.

6.1.1 Usage data

Student usage of the course blog and multimedia learning materials has remained consistently high throughout implementation of the HigherEd 2.0 program. Student usage of the blog (Figure 2) is typically cyclic but strong, averaging about 5-8 visits per week per student for the entire semester; students are clearly avid blog users. While students routinely view the blog, their comment rate appears to be quite sensitive to the local student environment and the set of incentives in place to promote active participation. The *student environment* concerning collaboration is important; in settings with a very small student population, it is not uncommon for students to collaborate almost exclusively face-to-face. However, with a larger student population, asynchronous collaboration via blogging, text messaging, etc. is much more common.

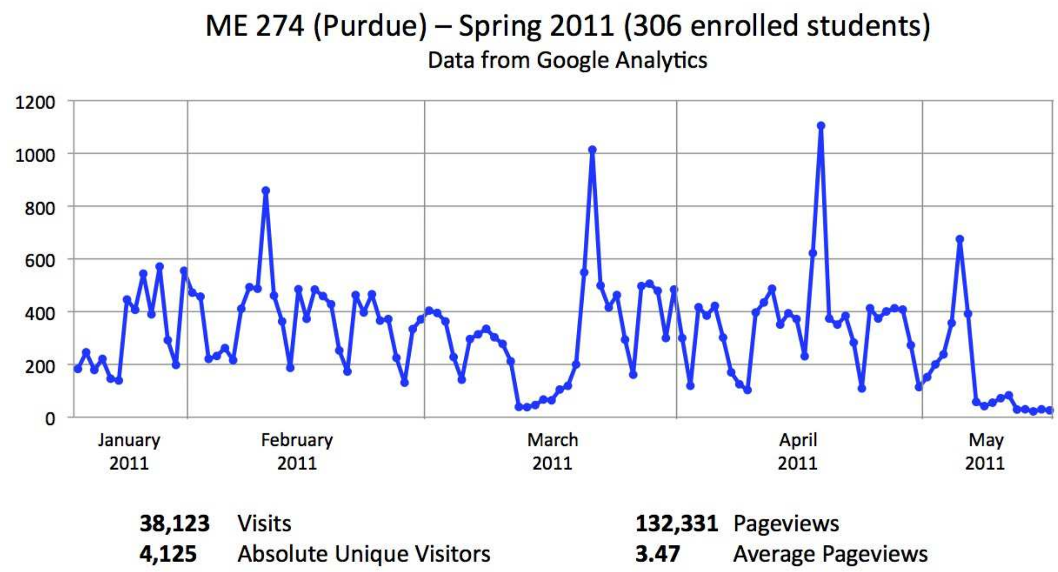
Perhaps more importantly, *incentives* provide an important impetus for students to actively use certain technologies, and our experience with blogging clearly shows the impact of incentives. For both Purdue courses and the Spring 2011 UVa course in Table 3, a small portion of the final course grade (3%) was tied to blog participation and asynchronous collaboration via commenting in threaded discussions on the course blog. The Spring 2009 UVa course used no incentives for blog participation. We discuss the role of incentives more in Section 6.2.2, but both our usage data, as well as student interview data detailed in Section 6.1.3, suggest that a course-grade-related incentive is an important motivator of early and active blog participation by students. When students are sufficiently motivated, fruitful discussions take place on the blog (Figure 1).

Site/Semester	*#comments*	*#comments/student*
UVa, Spring 2011	1012	9.45
Purdue, Spring 2011	2904	9.50
UVa, Spring 2009	26	0.40
Purdue, Spring 2009	1764	7.41

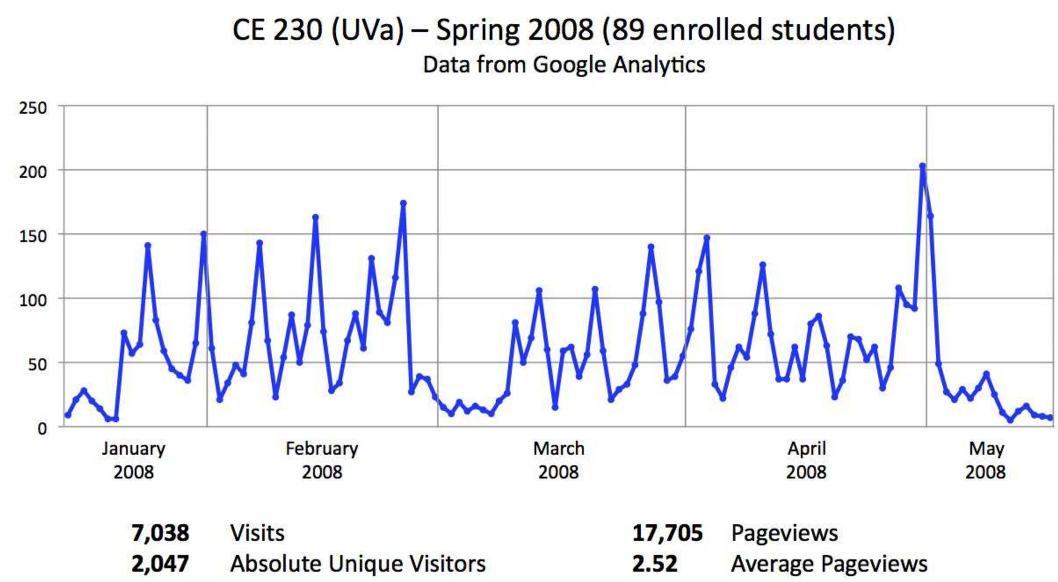
Table 3. Comparison of blog comments and per capita comment rate over two sites and two semesters.

6.1.2 Survey data

Survey data captures student attitudes about the HigherEd 2.0 paradigm and its perceived usefulness in helping them achieve course learning outcomes. Here we present a *very high-level summary* of the trends we have observed in our survey data, which has been collected over at least 6 semesters of HigherEd 2.0 courses at multiple institutions. Students across all semesters perceive the *lecture videos* to be of low-to-medium value, and this is largely because the lecture videos capture conceptual information and derivations. Students perceive this information to be less germane to their problem solving efforts in homework and exams, and therefore typically only consult lecture videos when they miss class due to illness or travel. Students report that they generally appreciate the *animations, simulations, and case studies* as



(a) Spring 2011 blog usage for Purdue (8.3 visits per week per student).



(b) Spring 2008 blog usage for UVa (5.3 visits per week per student).

Fig. 2. Blog usage during two semesters at two different sites.

valuable tools for a better conceptual understanding of the material. However, they also report that these components should be more closely integrated into course assignments in order for the learning impact to be maximized.

On the other hand, both the *course blog* and the *video solutions* are perceived to be of high value to students. Student report strong usage of the blog and typically find the anytime, anywhere collaboration through threaded discussions on the blog to be useful. Moreover, they report strong satisfaction with the learning environment shaped by the course blog. Students indicate that they appreciate the easy navigation, excellent organization, and convenient access. Video solutions are viewed similarly, with students generally appreciating their ease of use, expert perspective, and constant availability. Students report that the value of the video solutions increases as the course material become more conceptually complex (Orange et al., 2011) and the germane cognitive load therefore becomes higher.

6.1.3 Interview data

Student interview data reveals that the course blog and video solutions are considered extremely valuable by the majority of students. Purdue students offered comments like this about the course blog: "The discussions on the blog were very beneficial to view...I was promptly helped by both Prof. Krousgrill and other students." The virtues of video solutions were also recognized: "Helpful, good explanations, [I] would not get grade I am going to have without [the] videos", or "Very useful, well put together, easy to follow", or "They're super effective". On balance, student qualitative data is overwhelmingly positive about these and other features of the HigherEd 2.0 program. Nonetheless, students also recognize that social tools (such as the course blog) require a critical mass of users in order to deliver maximum value: "It's [the blog] only helpful if everyone uses it." Comments like these have stimulated our use of incentives to promote participation, yielding comments like this one from a Purdue student: "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."

Students also describe their experience with technology adoption, specifically their gradual adaptation to using the technology for learning. A UVa student: "I was really resistant to it [using 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: "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...". The data from the Spring 2009 UVa course in Table 3, from a semester when no blog participation incentives were in place, bear out this general feeling from students. Incentives certainly promote technology adoption, and they therefore help to create the user base necessary for social tools like the blog to be truly beneficial to students as a collaboration tool.

6.2 A conceptual framework for technology adoption

The diffusion of innovation framework provides a useful lens through which to view the HigherEd 2.0 program and our evaluation data. Rogers' theory states (Rogers, 2003) that diffusion is "the process by which an innovation is communicated through certain channels over time among members of a social system" (p.5). Rogers further explains the five key characteristics of innovations, and managing these characteristics has a profound effect on the rate of diffusion: (i) *relative advantage* (RA) is the value of an innovation compared to available alternatives; (ii) *compatibility* (Cp) captures the consistency of an innovation with the prevailing values of the user community; (iii) *complexity* (Cx) represents the perceived difficulty in using an innovation; (iv) *trialability* (T) refers to an innovation's ability to be used experimentally by the user base; and (v) *observability* (O) denotes the visibility of the innovation's impact on the community. The goal for any innovation is obviously to present high RA, Cp, T, and O, while introducing low Cx.

These characteristics, the goal of any innovation seeking widespread adoption, and the ways the HigherEd 2.0 paradigm expresses them, are shown in Table 4 and discussed in more depth in Sections 6.2.1 and 6.2.2.

HigherEd 2.0 feature	*RA*	*Cp*	*Cx*	*T*	*O*
goal of innovation	↑	↑	↓	↑	↑
blogging					
-communication	↑	↑	↓	↑	↑
-collaboration	−	−	↓	↑	↑
lecture videos	−	−	↓	↑	↑
video solutions	↑	↑	↓	↑	↑
student-generated content	−	−	−	↑	↑

Table 4. Summary of HigherEd 2.0 approaches within the diffusion of innovation "5 characteristics" framework (Rogers, 2003). [↑=high value, ↓=low value, − = neutral]

6.2.1 Complexity, trialability and observability

The shared, collaborative nature of HigherEd 2.0 strategies and resources essentially guarantee that the *trialability* and *observability* goals are met. Students perceive the course materials to be available for usage and experimentation anytime, anywhere, and (because of the public nature of the course blog) the impacts of this educational approach have high visibility among the student population. As described in the Introduction, the *complexity* associated with web 2.0 tools is generally low, but students do initially reserve some skepticism for the SGC components of their work. Because creating multimedia content for their peers typically presents a new approach to learning, students are not immediately confident that they will be able to successfully navigate the technology and produce a quality product. They quickly–and with little training–overcome this perception, but it nonetheless requires careful and frequent encouragement from the instructor to ensure that students understand and exploit the simplicity of current authoring tools.

6.2.2 Relative advantage and compatibility

In two technology areas (communication via blogging and video solutions), both the *relative advantage* and *compatibility* of the technology are essentially self-evident to students. Video solutions allow students to access expertise in problem solving when they need it, providing both a relative advantage and compatibility. The video solutions are a favorable alternative to time-constrained office hours, offer expertise that a student's peers might not possess, and fit smoothly into both the workflow and digital lifestyle of today's students. Students can simply download the videos to their portable device and use them anytime, anywhere. The course blog, with its RSS technology, platform-independence and robust navigation features, fits easily within students' daily workflow, and these features typically provide a performance advantage over a traditional course management system (CMS). However, for collaboration, students do not always perceive a relative advantage to the threaded discussions on the blog, nor does it always fit with their conception of what collaboration in course work looks like. Our experience has shown that students sometimes prefer synchronous, in-person collaborations with their peers on problem sets and exam preparation. Here, we have found that *incentives* are usually needed to jump-start student excitement about asynchronous collaboration via the course blog. A small amount of course credit can be awarded to promote participation in blog discussions. Remember also that although students frequently use social technologies, their attitudes about such technology for purely social purposes versus academic purposes can be quite different (Cole, 2009).

The lecture videos, according to student perceptions, possess little relative advantage compared to attending class meetings in person. Moreover, the length of the lecture videos (up to about 40 minutes) is somewhat incompatible with students desires; students would rather navigate directly to the section of the video with which they need help, instead of watching the entire video. While the lecture videos serve students well in specific circumstances (e.g., when they miss class due to illness), they generally are not compatible with student needs and therefore do not enjoy significant usage.

Student-generated content presents perhaps the most challenges to widespread adoption, and the mechanisms are largely about context. Students taking a HigherEd 2.0 course are likely also enrolled in non-HigherEd 2.0 courses as well. The dearth of usage of active learning techniques in higher education is well documented (DeAngelo et al., 2009), so it should be no surprise that the general learning environment often does not challenge students to create and share educational materials for their peers. In addition to students' perceptions about the complexity of producing multimedia materials, they are typically unconvinced of its relative advantage versus other approaches to learning, and often find it incompatible with the prevailing educational environment of which they are a part. Our work has shown that instructors can convince students of the benefits of SGC by explaining SGC pedagogy, modeling clear examples of good multimedia materials (such as video solutions), and providing user-friendly authoring options.

7. Summary and conclusion

The HigherEd 2.0 program has been deployed since 2006 in engineering education classrooms with strong success. The course blog provides the critical course backbone, from which instructors can serve multimedia content, and on which students can have productive asynchronous discussions. The HigherEd 2.0 paradigm is built upon the scholarship in engineering education, educational psychology, and cognitive science. In particular, it represents a real-world deployment of such powerful learning approaches as the worked-example effect. When placed in a cognitive load theory framework, the HigherEd 2.0 program clearly seeks to optimize cognitive load on the learner by adhering to best practices in multimedia production (Table 1) and blog usage (Table 2), both of which are built upon our extensive experience and evaluation data as well as the scholarship of multimedia pedagogy. When viewed through a diffusion of innovations framework, the HigherEd 2.0 program largely follows Rogers' "5 characteristics" framework (Table 4), with incentives and consistent coaching/reinforcement from the instructor motivating students to begin active use of the technology resources.

As new tools and technologies become available, their use in higher education will continue to evolve. The prevailing trend of increased "socialization" of technology, as well as its commoditization, will make the HigherEd 2.0 paradigm even more relevant in the future. The coming ubiquity of mobile tablet devices presents an essential opportunity for educators to transform the way they teach, engage students, share information, and collaborate. We suggest further, detailed evaluation of our strategies with diverse student populations, in multiple settings, and a variety of subject areas. Careful studies in real higher education environments, such as semester-long courses, will inform the on-going conversations about thoughtful technology deployment, and will surely suggest lively areas for future research.

8. Index of embedded hyperlinks

- ❶ sample lecture video: `http://people.virginia.edu/~ejb9z/Media/Sample_media/lecture_video_example.mov`
- ❷ sample video solution: `http://people.virginia.edu/~ejb9z/Media/Sample_media/vibrations_homework`
- ❸ sample learning module: `http://people.virginia.edu/~ejb9z/Media/Sample_media/impact_problems`
- ❹ sample case study: `http://people.virginia.edu/~ejb9z/Media/Sample_media/merry_go_round`
- ❺ sample use of color in video: `http://people.virginia.edu/~ejb9z/Media/Sample_media/p5_23_snippet.mov`
- ❻ video description of HigherEd 2.0 course blog: `http://people.virginia.edu/~ejb9z/Media/Sample_media/blog_description.mov`
- ❼ sample student-generated content: `http://people.virginia.edu/~ejb9z/Media/DynProb16_134.mov`

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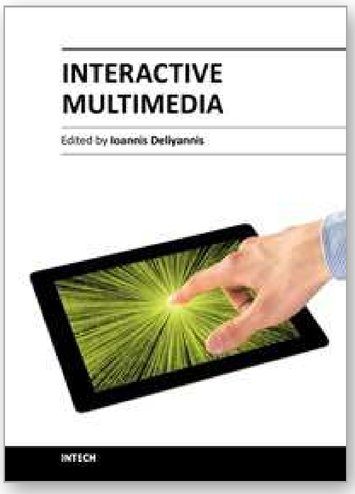

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Interactive multimedia is clearly a field of fundamental research, social, educational and economical importance, as it combines multiple disciplines for the development of multimedia systems that are capable to sense the environment and dynamically process, edit, adjust or generate new content. For this purpose, ideas, theories, methodologies and inventions are combined in order to form novel applications and systems. This book presents novel scientific research, proven methodologies and interdisciplinary case studies that exhibit advances under Interfaces and Interaction, Interactive Multimedia Learning, Teaching and Competence Diagnosis Systems, Interactive TV, Film and Multimedia Production and Video Processing. The chapters selected for this volume offer new perspectives in terms of strategies, tested practices and solutions that, beyond describing the state-of-the-art, may be utilised as a solid basis for the development of new interactive systems and applications.

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