121st ASEE Annual Conference & Exposition
Indianapolis, IN
June 15-18, 2014

Paper ID #10314

Using Recorded Lectures and Low Stakes Online Quizzes to Improve Learning Efficiency in Undergraduate Engineering Courses

Dr. David J. Dimas, University of California, Irvine

Dr. Dimas has over 25 years of experience which centers on consulting in simulation and design and developing and teaching a curriculum of related engineering analysis and product development courses in both commercial and academic settings. He served in a number of top-level management positions at both PDA Engineering and MSC Software including director of training services, customer support,educational sales and product documentation in the computer aided engineering (CAE) market. At MSC Sotware he pioneered new techniques and guided the development of two highly successful inter-active DVD based courses in the application of nite element analysis (FEA) in product development. He also developed a unique, low-cost, exible method to produce and maintain DVD versions of a curriculum of 15 courses related to CAE. Both provided increased knowledge access, transfer and retention. His industrial background also focused on applying theoretical aspects of numerical methods in simulation and design to wide variety of product development issues. He has served on the faculty at UC Irvine since I986 and has brought these practical applications into the classroom, providing students with signicant improvements in their ability to learn the theory and "art" of engineering simulation and design. He received his B.S. and M.S. in Mechanical Engineering and Ph.D. in Civil Engineering all from UC Irvine.

Prof. Faryar Jabbari, University of California, Irvine

Faryar Jabbari received his PhD, in Mechanical Engineering, in 1986 from University of California, Los Angeles. Since then, he has been on the faculty of the Mechanical and Aerospace Engineering Department of University of California, Irvine. His research interests are in control theory and its applications such as earthquake engineering and energy systems. He teaches classes in Dynamics, Control, Vibration and Engineering Mathematics.

Dr. John Billimek, University of California, Irvine

John Billimek is an Assistant Adjunct Professor in the Health Policy Research Institute in the School of Medicine at the University of California, Irvine studying approaches to improve the delivery of healthcare to disadvantaged patients with chronic disease. Dr. Billimek teaches statistics and research methods courses in UC Irvine's masters program in Biomedical and Translational Sciences, blending in-person and online activities to promote learning.

Using Recorded Lectures and Low Stakes Online Quizzes to Improve Learning Efficiency in Undergraduate Engineering Courses

Abstract

STEM disciplines, especially at research universities, have been measurably slow to integrate online modalities into undergraduate classes. Current and future students are now “digital natives” interacting with the world and absorbing information in a very “YouTube” style, characterized by short, on-demand, and entertaining chunks of information. Faculty have been reticent to adopt what they perceive to be unproven technologies while administrators often are unable to allow faculty extra time or budget to investigate the efficacy of new approaches to teaching. This paper describes the results of experiments designed to help improve this situation by accessing the effectiveness of two key online modalities that are often the easiest first steps for faculty to adopt and can be very effective in improving the operational effectiveness and learning outcomes of the course: Recorded lectures and Online Quizzes. Recorded lectures and Quizzes were integrated into two undergraduate engineering courses. The two courses were a sophomore level *Dynamics* class and a senior level *Finite Element Analysis* course. The *Dynamics* course is required and the enrollments range from 160-360, and the *Finite Element Analysis* course is an elective with enrollments between 60-80. In the *Dynamics* course, recorded lectures were often used in place of the live lecture and the in-class lecture time was often “flipped” and used for discussion and interaction rather than a traditional one-way lecture. In the *Finite Element Analysis* course, the lectures were recorded and made available to the students prior to the in-class version of the lecture. Quizzes were designed as an assessment tool (rather than purely for grading) aimed at "real time" feedback. This allowed both students and instructors to measure the learning achievements in the previous week of the course and let the instructor modify the subsequent week’s lectures accordingly. The results show that student-reported learning efficiency improves when recorded lectures are utilized. This was the case whether the class period was subsequently used to teach a similar lecture or if lecture time was flipped to provide more interactive discussion based learning. The availability of recorded lectures prior to class did not affect students’ decision to attend class. Students reported that having weekly “low stakes” quizzes and reviewing them in class helped them understand key concepts better. These results provide more evidence of an ever increasing amount of data that supports the learning efficiency gains that can be attained using a variety of hybrid course pedagogy and online learning modalities.

The debate over the need to adjust teaching methodologies based on the prominence of *Digital Natives* within undergraduate college courses has continued since the term originated (Presnky, 2001) early in this millennium. Recent studies have focused this debate away from the terminology and towards those activities that can help improve learning outcomes for students not easily described by a single term. It is important to consider the nature of how students interact with the world around them terms of behavior, learning styles, and use of technology. Students have indeed changed in the past two decades and adapting to those changes improves learning outcomes and student satisfaction.

Regardless of the technology utilized, students still prefer *Blended/Hybrid* classes that employ a course website to compliment live class meetings. In a recent study of over 112,000 undergraduate students, a majority (57.7%) indicated that their preferred type of courses were those that had some online components. Only 22.1 % of these students preferred courses with no online components and a very small 7.8% preferred online only courses (Allen, 2013). In the same study, students reported lecture capture as their number one priority for faculty to use more of in the future. Students also report that having some control of the pace of learning can help them be more effective (Wibee, 2011). This study was designed to address the changing needs of students and their stated preferences related to their use of recorded lectures and online quizzes in hybrid STEM classes. This paper summarizes some initial qualitative results that are part of a broader and more quantitative study that is planned for the 2014-2015 school years.

There is still some variation in the use and definition of term such as "blended" and "hybrid" in related research. To be clear, in this study the term “hybrid” is used to describe courses which have live, face-to-face meetings in a physical classroom each week and include a significant amount of additional materials as well as technical and procedural innovations available from the course website. This includes “flipping” the classroom in which lectures are recorded but students still attend live class for discussion of the material and other active learning activities.

Students Use of Technology

The debate over the nature of how students may or may not be learning differently continues. However, there is clear evidence that their use of technology continues to change. In a 2013 survey of student ownership of technology, laptops still occupied the top spot with over 89% of U.S. students reporting ownership (Allen, 2013). This number was 4% higher than 2012. Smartphones held the number 2 spot with 76% of student reporting ownership. Smartphone ownership, however, increased an impressive 15% between 2012 and 2013. Laptop and smartphone use by students significantly outpaces use in the general population. Student use of e-readers, desktop computers, and especially tablets all increased during the same period. However, students still use these devices less than the general population.

Students are using more technology in all areas (laptops, smartphones, desktops, tables and e-readers). However, according to the same study, smartphones posted an impressive 20% gain in importance to students while other devices remain the same or even dropped in value to students. While in-class use of smartphone's is not widespread (in fact many faculty discourage their use in class and some schools are experimenting with blocking WiFi access in lecture halls) more and more students report using smartphones to interact with the course website, take quizzes and listen to recorded lectures. Younger students reported using smartphones more than older students and used tablets less often, further accentuating the direction of the use of technology in the college level academic setting.

Recorded Lectures

While attendance in live lectures still remains the preferable method of instruction, utilization (and availability) of recorded version of lectures is increasing (Cardall, 2008; McCann, 2010; Berret, 2012). Other researchers caution that when live lectures are given, students who only view the recorded lectures are at a disadvantage when compared to those who use the recorded version of the lecture as a compliment to the live class attendance (Williams, 2012). Giving students the option to slow down the pace of the lecture or review selected topics via a recorded version of the lectures can be especially important for struggling students or those with language issues (Gyspers, 2011; Gosper 2008, Larkin, 2010). Additional studies found that there is a clear miss-match in the perception of the value of recorded lectures between students who had a 67% positive rating and faculty who had a 30% positive ranking (Gosper, 2008). Students want more recorded lectures but faculty do not always see the value or think they have the time to record the lectures. Often the issue is their perception of the required amount of work and unfamiliarity with the tools and process. The faulty members involved in this study required time to refine their lecture capture process. Both used different approaches and are still in the process of refining their use of tools and methodology to record lectures.

Recorded lectures can take a variety of forms from a simple audio-annotated screen captures to a lecture that is well rehearsed, story-boarded, and often recorded using at least one videographer. The latter "high production value" recordings are those that are often used in MOOC courses. Some recent research indicates that utilization and effectiveness of recorded lectures is directly related to the quality of the recordings (Yoon, 2011). Similar studies have found there are significant improvements in learning outcomes and student satisfaction when more time is spent in the design and preparation of the recorded lecture.

Online Quizzes

Studies have shown that students who feel "in control" of their learning perform better in class (Wiebe, 2011). Recorded lectures give students control of the pace of the learning and frequent online quizzes provide students with a good “dashboard” to monitor their performance in the class and then make corrections and prioritize their total workload as needed. These low-stakes, online quizzes also enhance student performance on final examinations and studies have shown that performance on weekly online quizzes do correlate with final exam performance (Dobson, 2008). In other studies, students rated low stakes and related “practice quizzes” as their favorite and most effective online activity (Brown, 2004).

Online, “low stakes” quizzes and polls were also utilized in this study to provide bi-directional feedback between students and faculty. Feedback from quizzes and polls was used by the faculty to modify content in subsequent lectures to ensure key concepts are understood. Time spent on each quiz was recorded along with quiz grades and were correlated.

Lecture Capture Techniques

In this study, faculty used three methods to create content that was subsequently captured adding both audio and video annotations with Camtasia. In order of difficulty from least to most, these are (1) document camera used in the instructors' office, (2) handwritten text, equations and drawings that were digitally captured via tablet computers and a stylus and (3) digitally typeset and drawn materials using text, drawing, and equation creation tools in PowerPoint.

Two different methods for lecture capture were used in this study. For the MAE80 class (*Dynamics*), a laptop computer with a tablet screen (Lenovo 230T) that allows easy use of stylus was used. All segments were hand-written, intentionally, to keep the material accessible and “warm.” The handwriting was clear and legible, with occasional use of different colored pens, but it did not look like professionally developed content (e.g. a textbook). Lectures were written ahead of time and the narration was added to the fully written (and drawn) pages to provide a reasonably fast pace to prevent boredom (those who wish, can always rewind). The effort is not trivial. The tablet, while one of the easiest one tested, required care and a deliberate pace -- perhaps twice the time it would take to write neatly on paper.

Lenovo’s 230T Tablet Computer

For the MAE152 class, lecture notes were prepared using a combination of PowerPoint and some handwritten but digitally captured notes using the Pentel’s Airpen. The AirPen uses a typical ink pen surrounded by electronics that allow the separate tracking device (attached to the top of any sheet of paper) to capture the written content. This provides a very natural feel to the writing.

Pentel's AirPen

For a majority of the recorded lectures for MAE152, existing handwritten lecture notes were converted to PowerPoint images using a combination of student workers and faculty. This proved to be a very effective process since the majority of the repetitive work was done by much lower cost student labor and faculty served to review and check the work. Student workers converted the first 10-20 pages of the content with frequent feedback from the faculty. However, students quickly got a "feel" for the process and improved the required drawing and equation creation skills which allowed subsequent conversions to require much less faculty interaction.

For both classes the lecture materials were annotated with an audio track and additional notations via stylus or mouse input by using Camtasia Studio v8. When the lecture materials were prepared in this manner subsequent recording of lectures took much less time than would have been required to teach a live version of the same content. During a live lecture the "dead time" required to write content on the board can be a valuable part of the lecture - allowing students to copy the content into their notes, or even better, process the content while the instructor is not speaking. Students viewing a recorded lecture do not need this "dead time" since they can start and stop the lecture as needed.

This reduction in the length of a recorded lecture when compared to the same lecture given live is more pronounced in STEM classes. Complex drawings and detailed mathematical equations are commonplace in STEM lectures but take time for the instructor to transcribe and for students to copy into their notes.

In an effort to resonate with some of the *Digital Native* characteristics of the students in this study (watching a YouTube video with an average length of 4 minutes), recorded lectures were cut into shorter chunks. Content that was often presented in a continuous live lecture ranging between 50-80 minutes was cut into short segments that ranged from 9 to 34 minutes.

Once these lectures were recorded they were submitted to the campus servers which would further compress the files and then provide URLs for both a PC and iOS version of the lectures (MPEG-4 and Windows Media File). Faculty then posted these URLs to the course website.

Study Design

Two courses taught in the Department of Mechanical and Aerospace Engineering in the winter quarter of 2013 were used in this study. Each course was 10 weeks in length and each carries 4.0

units of credit. The first class was a lower division course in *Dynamics* which is a required class for several engineering undergraduate degree programs. Enrollment in this course can vary from 160-360. This course covers kinematics and dynamics of particles and rigid bodies using Newton-Euler, Work/Energy, and Impulse/Momentum methods. The course is 4.0 units including 1.0 unit of design. The second course in the study is an upper division elective course titled, *Introduction to Computer-Aided Engineering (CAE)*. This course covers the theory and application of the finite element method to practical design issues. The course is also 4.0 units and includes 2.0 design units. The faculty for each of these courses has taught their respective courses for over 10 years.

Both courses were taught with the use of a related online course website. These websites utilize the Moodle learning management system. The University provides support for these websites via a set of campus resources structured under a unit called the Distance Learning Center (DLC). The DCL also supports a large number of purely online courses that are part of the University's extended education, Open Courseware and MOOC (Massively Open Online Course) offerings. The DLC provided guidance in use of the Moodle system, technical support for enrolled students and some instructional design guidance for the faculty for both courses in this study.

In both classes recorded lectures were captured as noted above and then added to the resources available to the students on the course website. Each course followed a different method with respect to using the recorded lectures. In the *Dynamics* course, the focus was on the use of recorded lectures as a component of a "flipped" classroom. In this initial experiment, recorded lectures were provided for the first 20% to 30% of the 10-week course in which the material in the text was supplemented by significant amount of additional content. The lecture segments were relatively short, ranging from 8 to 15 minutes each. This class meets twice a week for 80 minutes. The corresponding recorded lectures averaged just over 40 minutes, considerably less than the time required to present this same material live. The recordings were made to ensure students have access to the material and to make sure there was enough time to incorporate the extra material not always presented during the live lectures due to time constraints. A PDF version of the lectures was also provided for possible paper-based (and static) review and to allow students to take notes directly on the paper or electronic copy. During those weeks when recorded lectures were used, the live lecture period was "flipped" and used for answering questions, working out homework problems and additional examples. Each recorded lecture in the *Dynamics* class was followed by a brief, low-stakes, quiz (3 to 5 multiple choice questions). The questions were conceptual and were meant to evaluate the level of comprehension of basic concepts as well as the ability to apply the concepts to different -- and more complicated -- problems. The results of these quizzes were used as a feedback mechanism to help the faculty modify subsequent lectures.

In the *Finite Element Analysis* class, lectures were recorded for 50% of the 10-week course. To contrast the approach used in the *Dynamics* class, the *Finite Element Analysis* class lectures were usually made available to the students 3-5 days prior to the live lectures and during each week's live lectures, the same lecture content was covered as was available in the recordings. Recorded lectures for the *Finite Element Analysis* class ranged in length from 10 to 29 minutes. In contrast to the *Dynamics* class where a quiz was given after each segment of the recorded lectures, the *Finite Element Analysis* course included a single required quiz taken at the end of each week. These quizzes were "low stakes" comprising (in total) less than 5% of a student's grade. The quizzes were designed to access key learning objectives for the previous week and, similar to the *Dynamics* class, served as a feedback mechanism both for the students and the instructor. Quizzes varied in length from 4-8 multiple choice, true/false and short answer responses. The faculty reviewed the answers to the quizzes via live feedback in the lectures. In the *Finite Element Analysis* course, students were also given a "Muddiest Point" poll via the online course shell in which the students were asked which of 4-6 topics covered during the previous week was the most difficult to understand. The faculty used both quiz and poll results as a feedback loop to alter future lectures similar to the process used in the *Dynamics* course.

The quizzes were the most challenging parts of the endeavor for both classes: short enough to prevent loss of interest while covering enough material; low stakes enough to prevent any inducement to dishonesty; yet important enough for students to take them and devote a reasonable amount of attention. Their short term value to the instructor was to identify concepts that remain problematic for a large number of students. Longer term, they serve as guide to students regarding what concepts are considered important by the instructor.

In the last week of both classes a survey was conducted to assess student feedback on the use of various recorded lectures and online quizzes in these courses. These surveys were integrated into the online course shell as ungraded student *Polls* and could be filled out in less than 10 minutes. Aggregate data was also collected related to student activity on the website and their performance in class assignments, quizzes and exams.

Results

A majority of students in the study indicated that the overall quality of the learning improved when recorded lectures were available. Students also indicated that the most valuable aspect of having recorded version of the lectures available on the course website was being able to access them after class to review topics they did not fully understand. Access to the record lecture prior to coming to class was also highly rated by the students. In both classes students agreed that recorded lectures gave them more control of the pace of learning, were useful to listen to after class and should be available in more classes. Interestingly, the availability of online versions of the lectures did not have a significant effect on students reported motivation to attend class.

Table 1. Recorded Lecture Survey	Mean Student Response (Standard Deviation) 1 = strongly disagree, 5 = strongly agree	
Student Responses to the following questions related to recorded lectures:	**MAE152** (Finite Element Analysis) N=78	**MAE80** (Dynamics) N=193
Gave me more control of the pace of learning	4.54 (0.61)	4.38 (.075)
Helped me decide when to come to lecture	3.38 (0.88)	2.9 (1.11)
Should be available in more classes	4.24 (0.73)	4.13 (0.88)
Made it less likely that I would go to class	2.95 (1.09)	2.24 (1.06)
Had no effect on what I learned in this class	2.03 (0.78)	1.99 (0.98)
Were useful to listen to after class	4.29 (0.78)	4.41 (0.69)

The students also filled out a follow-up survey related to recorded lectures that was focused on the possibility of having all lectures recorded and posted to the class website after class. These results are presented in Table 2. Students reported that they did not support the idea of having only recorded lectures (no live lectures) even if we added more live discussion sections.

Table 2. Recorded Lecture Follow-Up Survey	Mean Student Response (Standard Deviation) 1 = strongly disagree, 5 = strongly agree	
Student Responses to the Following Situation: We are considering recording all lectures and putting them online after class.	**MAE152** (Finite Element Analysis) N=78	**MAE80** (Dynamics) N=193
I think we should have recorded lectures only and add more discussion sections	2.91 (1.19)	2.18 (1.06)
Even with recorded lectures available I still want live lecture to plan my day and ask questions	3.81 (0.91)	4.22 (0.82)
I'm not sure I have the discipline to pace myself and stay focused without attending a live lecture	3.22 (1.06)	3.31 (1.16)

Students in MAE80 are generally two years younger than students in MAE152 and this age difference resulted in slightly different responses. Younger students tended to be slightly stricter with respect to attending lectures if a recorded version was available. Older students were a bit more open to only having recorded lectures and increasing the number of discussion sections although the older group was still fairly neutral on this response.

In general, recorded lectures were well received (repeated surveys, in different contexts over a two year period) and showed only a small fraction of students unsatisfied (6-8% typically) and strong majority either highly appreciative or modestly supportive. There was significant number of requests for narrated homework solution, as the typical static posting of solutions often lack any explanation on why specific steps are taken or how the solution technique `flows'. This has led to incremental enhancements: additional segments covering important examples or concepts or the addition of weekly quizzes throughout the course.

With respect to online quizzes, students reported that taking them and reviewing the answers in class helped them understand the materials and prioritize key concepts. In contrast with these results, students also reported that taking the online quizzes had little effect on their study habits.

Table 3. Quiz Survey	**Mean Student Response** (Standard Deviation) 1 = strongly disagree, 5 = strongly agree	
Student Responses to the following questions related to online quizzes:	**MAE152** (Finite Element Analysis) N=78	**MAE80** (Dynamics) N=193
Helped motivate me to study for class each week	3.46 (1.03)	3.18 (1.05)
Had no effect on my study habits for this class	2.99 (1.07)	3.03 (1.09)
Taking quizzes online and reviewing them in class he me understand the material	3.81 (0.79)	3.97 (0.82)
The online quizzes helped me prioritize key concepts class	3.58 (0.96)	3.83 (0.84)

Regression analysis on time spent on quizzes and recorded lectures and final grade in the class will be added prior to the final submission of the paper. The initial indications are that there is a positive correlation between time spent on quizzes and quiz grade and time spent listening to recorded lectures and final course grade.

Conclusions

Recorded lectures were used differently in the two classes in this study. In the *Dynamics* course subsequent lectures were "flipped" and used for both discussion and to work out additional homework problems. In the *Finite Element Analysis* course subsequent lectures were a "repeat" of the same content that was available in the recorded lectures. In both cases, however, the responses from the students were clear - they would like to see more lectures in more classes recorded and available to them <u>and</u> they want to continue having live lectures. Interestingly, the availability of online versions of the lectures did not have a significant effect on students reported choice to attend class. This result is similar to other research (Allen, 2013) where only

14% of students reported they would skip class if recorded versions of the lectures were available online. This percentage of students who would skip class in this situation remained constant from the survey from the previous year indicating that the attendance issues when recorded lectures are available are not increasing. The age of the students did have an effect on their responses; younger students reported they would miss class less than older students when a recorded version of the lecture was available. This is different than other studies which have reported that younger students would miss more class when recordings of the lectures are available. One possible cause of this difference is that the courses in the current study are only from the STEM disciplines offered at a major research University while the previous study included a much broader set of classes at both research and non-research schools.

The compressed nature of recorded vs. live lectures was a key benefit of the lecture capture process producing an online asset that is more effective for students. Both faculty agreed that the length of a recorded version of a lecture was roughly half that of the corresponding live version. Another benefit of recording a lecture is that the materials have been essentially "rehearsed" during the process of capturing the content electronically which forces additional planning and re-evaluation, improving the quality and usability of the recorded lecture.

The quality of the recorded lecture is key to its effectiveness as a learning tool. However, simply having a videographer sit in the back of the classroom and record a live lecture does not always yield an asset that is valuable to students. This is especially true since lectures recorded using other lecture capture methodologies are much shorter and therefor more accessible to students. Conversely, spending the time and money to produce a lecture that would be worthy of a PBS special may not produce results that are improved enough to warrant the investment of time and money. In this study a modest amount of design time, coupled with a similar investment in learning various lecture-capture technologies, proved to be a sustainable model that provided measurable results.

Feedback from the students indicated a preference for shorter segments of lectures. Students reported that it was much easier to insert several short viewings of recorded lectures into their busy schedules than it was to set aside time to watch a full hour lecture. Faculty plan to keep future recorded lecture segments higher than the YouTube average of 4 minutes but much lower that of the traditional lecture period of between 50-80 minutes.

A review of student activity data on the course websites also indicated that students watched recorded videos more often when the posting on the course website indicated the length of the video. While the students could have easily opened the video to see how long it was, the minor additional work for the faculty to annotate the website with the length of each video seemed to increase the number of views of each lecture. These and other related minor adjustments to the design of the course website focused on increasing student use of online assets seemed to have a highly positive ROI.

One of the most interesting insight that resulted from this study was that our current generation of students, when given additional resources such as recorded lectures will indeed use them often *in addition* to what they are already doing (attending lectures). Continued research is needed to quantify this and to determine how much additional hybrid course related work they can absorb since clearly they have a limited bandwidth.

Students indicated that they find short, low-stakes, weekly quizzes a valuable learning tool. The automated grading of the quizzes significantly reduced grading effort and allowed the faculty to immediately use the results of the quizzes as a feedback-loop to modify subsequent lectures. The work required for the initial development of these quizzes was effectively mediated by the use of student workers. Utilization of these online assets in subsequent offerings of the course was relatively easy and allowed the faculty to build upon the existing asset, improving the effectiveness of the online quizzes, with each iteration.

It is interesting to note that while students found quizzes helpful as a learning tool; they did not see them as an asset that *motivated* them to study. Generally students report that midterm and final exams provide significant motivation to study. One explanation is that these quizzes were too "low-stakes" (3-5% of their grade) and study time is often proportional to the weighting of class assignments. For future offerings of these courses, faculty plan to add more weight to quizzes and possibly add quiz points directly to a midterm or final exam score.

There was a correlation of time spent on quizzes and both quiz grades and course grades (need to expand)

In this work faculty invested substantial time to create recorded lectures, quizzes and flipped classrooms. Based on student feedback, changes to these assets and how they were delivered to the students were then made aimed at increasing student utilization of this online content. During this process, faculty considered that students are now more often characterized as *Digital Omnivores* (Li, 2012) in that they use and consume information from a variety of computational devices (laptops, smartphones, desktops and tablet devices) more equally. Therefore, changes were then focused on resonating with the way students use currently use technology and included for example, offering shorter segments of recorded lectures in formats compatible with <u>both</u> major smartphone platforms (Android and iOS).

One key take away from this study was that adding online assets is not enough. Online content must also consider the changing nature of how students are using technology to insure these assets are accessible, attractive and fully utilized by students.

Further Work

This initial work related to online quizzes, recorded lectures and flipped classrooms has been primarily based on qualitative responses from student surveys. However, the results have been positive enough to encourage further quantitative research and to expand to include a broader spectrum of online asserts. This additional work will also consider changes in student use of technology with a particular emphasis on Smartphones.

The key focus of our future work is not only to create a variety of online assets for hybrid classes but also to investigate how to get students to spend more time using these online components of the class. As with many commercial products, much of the initial use is based on the existence of the content and its perceived value. Subsequent expansion of use is often rooted in, stability and ease-of-use of the product. Together both initial and long-term use is a function of quantity and overall quality of the assets (both content, organization and GUI), faculty interaction, stability of the platform and customer support. To quantify this broader spectrum of the quality and effectives of hybrid courses, future work will also include a a Hybrid Course Maturity Model (HCMM) which includes quality and quantity ratings in the following areas : (1) recorded lectures (2) discussion forums (3) online quizzes (4) online worked-out homework (5) online homework submission and grading (6) student polls/feedback (7) online course shell design and ease of use (8) technical support and (9) LMS platform stability. Coupling this with the knowledge of trends in student use of technology (especially Smartphones) should provide added insight aimed at improving the effectiveness of hybrid STEM courses.

References:

Naseer, M. (2012). Digital Omnivores, Social Media and Social Capital: Expatriates interactions using Smartphones in Stockholm (Doctoral dissertation, Södertörn University).

Li, D., & Segal, B. (2012). The Changing Landscape of The Canadian Mobile Audience. International Journal of Mobile Marketing, 7(1).

Allen, I. E., & Seaman, J. (2008). Staying the course. *Babson Survey Research Group: The Sloan Consortium*.

Balaji, M. S., & Chakrabarti, D. (2010). Student interactions in online discussion forum: Empirical research from 'media richness theory'perspective. Journal of Interactive Online Learning, 9(1), 1-22.

Beck, R. J. (2010). Teaching international law as a partially online course: The hybrid/blended approach to pedagogy. International Studies Perspectives, 11(3), 273-290.

Ben-Ari, M. (2001). Constructivism in computer science education. *Journal of Computers in Mathematics and Science Teaching*, *20*(1), 45-73.

Bernard, R. M., Brauer, A., Abrami, P. C., & Surkes, M. (2004). The development of a questionnaire for predicting online learning achievement. *Distance Education*, *25*(1), 31-47.

Bennett, S., Maton, K., & Kervin, L. (2008). The 'digital natives' debate: A critical review of the evidence. British journal of educational technology, 39(5), 775-786.

Berrett, D. (2012). How 'flipping' the classroom can improve the traditional lecture. *The chronicle of higher education*, *12*.

Branoff, T. J., & Mapson, K. (2009). Large course redesign: Moving an introductory engineering graphics course from face-to-face to hybrid instruction. In Southeastern Section Meeting the American Society for Engineering Education, Marietta, Georgia (pp. 5-7).

Boling, E. C., Hough, M., Krinsky, H., Saleem, H., & Stevens, M. (2012). Cutting the distance in distance education: Perspectives on what promotes positive, online learning experiences. The Internet and Higher Education, 15(2), 118-126.

Clark, R. C., & Mayer, R. E. (2011). E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning. Wiley. com

Gosper, M., Grenn, D., McNeill, M., Phillips, R., Preston, G., & Woo, K. (2008). The impact of web-based lecture technologies on current and future practices in learning and teaching. Australian Learning and Teaching Council.

Gysbers, V., Johnston, J., Hancock, D., & Denyer, G. (2011). Why do Students still Bother Coming to Lectures, When Everything is Available Online?. *International Journal of Innovation in Science and Mathematics Education (formerly CAL-laborate International)*, *19*(2).

Lara, E., & Okhuysen, V., (2012) "Improving a traditional engineering lab thoguh conversion into a Hybrid course," in Proceedings of the 2012 ASEE PSW Section Conference, San Luis Obisbo.

Larkin, H. E. (2010). But they won't come to lectures..." The impact of audio recorded lectures on student experience and attendance. Australasian journal of educational technology, 26(2), 238-249.

Means, B., Toyama, Y., Murphy, R., Bakia, M., & Jones, K. (2010). Evaluation of evidence-based practices in online learning: A meta-analysis and review of online learning studies.

Merisotis, J. P., & Phipps, R. A. (1999). What's the Difference?: Outcomes of Distance vs. Traditional Classroom-Based Learning. Change: The Magazine of Higher Learning, 31(3), 12-17.

Palloff, R. M., & Pratt, K. (2002). Lessons from the cyberspace classroom: The realities of online teaching. Wiley. com.

Picciano, A. G. (2002). Beyond student perceptions: Issues of interaction, presence, and performance in an online course. *Journal of Asynchronous learning networks*, *6*(1), 21-40.

Prince, M. (2004). Does active learning work? A review of the research. Journal of engineering education, 93(3), 223-231.

Redmon, R. J., & Burger, M. (2004). WEB CT discussion forums: Asynchronous group reflection of the student teaching experience. Curriculum and Teaching Dialogue, 6(2), 157-166.

Riffell, S., & Sibley, D. (2005). Using web-based instruction to improve large undergraduate biology courses: An evaluation of a hybrid course format. Computers & Education, 44(3), 217-235.

Romero, C., Ventura, S., & García, E. (2008). Data mining in course management systems: Moodle case study and tutorial. *Computers & Education*, *51*(1), 368-384.

Rourke, L., & Kanuka, H. (2009). Learning in Communities of Inquiry: A Review of the Literature (Winner 2009 Best Research Article Award). The Journal of Distance Education/Revue de l'Éducation à Distance, 23(1), 19-48.

Sadaghiani, H. R. (2011). Using multimedia learning modules in a hybrid-online course in electricity and magnetism. Physical Review Special Topics-Physics Education Research, 7(1), 010102.

Springer, L., Stanne, M. E., & Donovan, S. S. (1999). Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis. *Review of educational research*, *69*(1), 21-51.

Soong, S. K. A., Chan, L. K., Cheers, C., & Hu, C. (2006). Impact of video recorded lectures among students. Who's learning, 789-793.

Tallent-Runnels, M. K., Thomas, J. A., Lan, W. Y., Cooper, S., Ahern, T. C., Shaw, S. M., & Liu, X. (2006). Teaching courses online: A review of the research. Review of educational research, 76(1), 93-135.

Yoon, C., & Sneddon, J. (2011). Student perceptions of effective use of tablet PC recorded lectures in undergraduate mathematics courses. International Journal of Mathematical Education in Science and Technology, 42(4), 425-445.

Wiebe, E. N., BranoffF, T. J., & Shreve, M. A. (2011). Online Resource Utilization in a Hybrid Course in Engineering Graphics. Advances in Engineering Education.