International Journal of Engineering Education Vol. 31, No. 2, pp. 461–475, 2015
Printed in Great Britain
0949-149X/91 $3.00+0.00

Instituting and Assessing the Effectiveness of Focused e-learning Modules in Engineering Education*

GILLIAN M. NICHOLLS
Southeast Missouri State University, Quantitative Methods—Dept. of Accounting, One University Plaza, Mailstop 5815, Cape Girardeau, MO 63701, USA. E-mail: gnicholls@semo.edu

SHERRI L. RESTAURI
The University of Alabama in Huntsville, Distance Learning for Academic Affairs and College of Engineering, Room 127 Wilson Hall, Huntsville, AL, 35899, USA. E-mail sherri.restauri@uah.edu

This study examines the development, utilization, and assessment of e-learning modules designed to assist students in mastering core concepts in a hybrid undergraduate engineering economic analysis class. The online learning aids focused upon key conceptual material that students had historically experienced difficulty learning within this course. The modules consisted of a short audio/video "micro-lecture" (ML) recording about a particular topic accompanied by downloadable reference documents containing the associated ML PowerPoint® slides and example problems. Automated assessment exercises were created for students to practice their grasp of the concepts. The online assessments and reference materials were hosted within the course learning management system, while the ML videos were accessed through a separate distance learning platform. Detailed records of students' use of the MLs, online assessment scores, exam performance, prior academic performance, and demographic variables were gathered. This data was compared to results for students in two previously taught sections who served as controls for the study. Although preliminary data indicates that the focused modules have been helpful to some students, data results overall were inconclusive in demonstrating improved learning outcomes across the board for students in the targeted course. Recommendations for improvements to data collection across multiple selections, methodology design, and e-learning tool implementation are provided for future studies.

Keywords: e-learning; micro-learning; hybrid; micro-lecture; learning management system; student persistence; online learning resources; lecture capture; Mediasite; Panopto; generative learning; active learning; learning assessment; m-learning; analytics; dashboard

1. Introduction

Society benefits by having sufficient numbers of STEM professionals productively engaged in the workforce. To keep pace with the demand, the number of graduating students earning degrees in these fields is a subject of great interest to society in general and educational professionals in particular. In a difficult economic environment, it becomes especially important to make good use of constrained educational resources to increase the likelihood that STEM students will acquire the knowledge required to successfully complete coursework and progress towards degree achievement. Students who are unsuccessful in completing a required course experience disruptions in the pattern of course-taking, potential delays in degree acquisition, additional financial cost, and ultimately may choose not to persist in earning a STEM degree. These non-persisting students represent a loss from the STEM pipeline and the future STEM workforce. Micro-scale STEM persistence within required coursework is an essential component of macro-scale persistence to earning a STEM degree. This is critical when considering the engineering coursework that students typically reach after completing the first two years of gateway courses where much of the loss from the STEM pipeline occurs.

The higher education system is straining under a combination of trends affecting academia. Garrett and Poock [1] and Hansen et al. [2] have discussed the calls for universities to reduce the cost and time required for students to complete their education. At the same time, Colleges of Engineering are experiencing longer times from matriculation to graduation as the volume of course content considered essential has risen but more students are entering less prepared to perform at a college level [3, 4]. Weisbrod and Asch [5] have documented the slowing rate of funding increases for state-supported universities as the poor economic climate has stressed state budgets. Dunbar et al. [6] and Logue [7] reported that students are under similar pressures to finish their education, obtain employment in a period of economic strain, and repay student loans that have reached historic proportions [8]. Non-traditional students who often juggle employment and family responsibilities in addition to school are becoming the norm [9]. These trends have impacts that manifest within the classroom. While faculty generally select a textbook for their

* Accepted 1 September 2014.

courses, believing it is a key resource, students often resist acquiring textbooks due to economic costs [10], and are less likely to use them regularly than in the past [11]. Parry observed that renting textbooks or purchasing electronic editions are potential cost-saving options, but many students simply do without.

Overall, both universities and students have a stake in the efficiency and effectiveness of engineering education. The adoption of technologies to lower students' invested costs overall and to supplement learning has grown in appeal within higher education. Universities and faculty are dealing with constrained resources to deliver education, while engineering students are dealing with increased content mastery expectations, rising textbook/tuition/material costs, and a challenging employment market. Developing and using web-based learning materials that can aid students in acquiring and applying knowledge is an approach to meeting the needs of both parties. The plethora of new technology to enable communication and educational content delivery offers a way to provide access to learning materials designed to suit a wide variety of learning and teaching styles [12–14]. With so much at stake in how students and universities handle the investment of time and money in engineering education, it is important to make sure opportunities to improve the process are seized.

2. Theoretical framework

Generative and active learning are the underpinning educational theories supporting this research study [15–17], as generative learning indicates that students achieve better learning when they are active participants in the process of learning rather than passive recipients of information imparted by an instructor. By actively engaging in the learning process, students more deeply understand the information and extend their prior learning by associating the new information with the earlier framework. Stronger associations are created if the new information fits the earlier framework, since the students' prior learning is being recalled from long-term memory. This leads to students being better able to meaningfully internalize the new concepts. When students make a connection between previously and newly learned concepts, knowledge is generated. Wittrock extended this theory to inform instructional design, stating that students would benefit from learning strategies that used motivation, attention, memory, and comprehension to generate knowledge [18]. This form of instructional design focused on directed learning strategies to aid students in increasing their reading comprehension skills. Yet it has implications for more general learning and engineering education in particular. Students who are motivated to generate knowledge, and have a sense of personal control over the process, are more equipped to successfully manage the process and act when they detect a problem in the learning progression. Engineering students are trained to study problems logically, identify root causes, generate potential solutions, analyze the alternatives, select the best choice, implement the alternative, and audit the results. Learning strategies that encourage engineering students to practice this craft and become engaged in the process reinforce this necessary problem solving mentality. Lee et al. [19] concluded from a review of the generative learning literature that actively engaged students are better able to remember, comprehend, and use higher order thinking for new information.

Vygotsky [20, 21] theorized that the combination of culture and social interaction had an effect on children's learning ability. Children could theoretically be helped in knowledge acquisition by receiving a wider exposure to diverse cultural and social milieus. Vygotsky's theory included the "zone of proximal development" (ZPD), suggesting that students would learn more by being guided through the process by a skilled instructor as opposed to just independent learning efforts. Thus the degree of social interaction between the student and instructor positively affected cognitive knowledge acquisition. Bruner [22] created the theory of instructional "scaffolding" to examine children's language acquisition through parental encouragement and guidance via supportive activities. The theory of scaffolding indicates that students initially rely on the support as they are learning, but that the support can be reduced as the student advances to a higher state of independent learning competency. Together, both generative learning theory and the Vygotskian/Brunerian framework of ZPD and scaffolding the learning tasks for students were the underpinning for implementation of this blend of educational technology support tools to enhance student learning outcomes. Students are guided at first by the instructor and then empowered by the support tools to extend their grasp of core concepts, test how deeply they learned them, and take ownership of quickly resolving misconceptions. Students can select which of the online eLearning supplements (videos, handouts, practice quizzes, solved example problems, etc.) are best suited to their learning style preference.

Once students and the instructor become aware that a gap in conceptual understanding exists, the obvious question is how to correct the problem, and this is where just-in-time (JIT) technologies should be able to assist both the faculty and the students in learning in their time and space. Some students may need to spend additional time working to grasp the concepts and/or seek additional help in understanding core concepts necessary before mastering major chunks of knowledge that are central to progressing further in this foundational course. The combination of online technologies chosen for this study were selected specifically to address the issue of providing additional help to students based on the functionality available therein. Online resources provided via a learning management system (LMS) are normally available at any time that the student chooses to use them, without time or day constraints otherwise presented by some in-class exercise opportunities. This availability of online resources is further enhanced now that most LMS providers are offering mobile apps or functionality to truly extend learning to JIT with respect to anytime, anywhere, and with any device. Further, these resources can be created in advance of the class or during regular instructor preparation time and, once created, they require little additional effort to provide assistance to multiple students. Thus they serve as a "force-multiplier" for instructors who may choose to implement this student performance management model into their own STEM or otherwise foundational course within their discipline. The ability of the student to "self-serve" with the LMS through prescribed e-learning content modules is similar to the educational dashboard model that is growing in popularity with e-learning portals [23]. In this study, the application of such an educational dashboard for self-service, however, is contained within individual courses for each student's own personal use.

3. Literature review

The concept of making online educational materials available to students for self-study outside of traditional lectures has been extensively explored in the past within the fields of educational technology as well as specifically within engineering education. The technique of supplementing lectures to support students who were not able to attend to partake of lectures has grown tremendously throughout various disciplines and across both undergraduate as well as graduate levels of course offerings on the college campus. Where the field of Distance Learning (DL) sprang up originally to offer post-secondary education to students who were limited by physical distance or scheduling difficulty, a shift into the more common JIT course content model is becoming more commonplace. The concept of providing content anywhere, anytime is not new. However, the evaluation of this content's utility and actual detailed usage patterns by students is less commonly found in the literature in engineering education. Further, the prescribed and traceable application of designated learning modules based on a particular student's given performance at varied spots throughout a course is an innovative aspect of this study.

3.1 Content of learning modules

Recent and previous studies by Mayer [24, 25] discussed using multimedia teaching tools to facilitate students' acquisition of problem solving skills. He explored a cognitive theory in which the multimedia must reinforce one another in conveying knowledge to avoid distracting students with too much information delivered under conflicting media inputs [26, 27]. This arose from the theory of cognitive load based upon cognitive psychology [28–33]. In this theory Chandler and Sweller state that human memory can be overloaded by receiving too much information via "extraneous cognitive load" and some "channels" of information delivery are more effective. Thus a video that includes a narrator explaining an animation is better received than a combination of written and narrated material. Instructing students with a combination of separate sources such as text and imagery increase the cognitive load and is counterproductive to aiding learning. Austin [34] tested the theory of cognitive load by preparing multimedia lessons, showing the lessons to 75 randomly assigned psychology students, and then administering a short exam. The multimedia treatments included combinations of animation, narration, text, and text repositioned on the screen from one image to the next. Austin found that the combination of information delivery methods explained some of the variation observed, but that other factors not identified may influence the educational effectiveness. Wong et al. [35] reported that animation is a better channel to relay transient information in short segments, but static graphics are a better channel for students to absorb transient information in longer segments. These studies provided strong guidance on the appropriate types of content to include in supplemental online material but looked less at usage and targeted applications.

3.2 Format of course and length of videos

Much of the prior research in measuring the results of online learning materials has focused upon fully online courses (in which all educational content is delivered without in person lecture attendance) or hybrid course formats (some face-to-face interaction occurs) in which recordings of full lectures (either audio only or audio-visual) are made available to students in addition to in person lectures. An example of the hybrid approach is the practice of making audio or audio/video recordings in mp3 format available for students to download and play at their computers or on mobile devices (e.g. an iPod®) asynchronously and in a JIT or on-demand request. Such "podcasts" can be played on mp3 devices, allowing students to choose the time and place at which they consume the learning material. The podcasts may be recordings of the in-class lectures or separate materials.

One concern expressed through the literature about offering online materials to supplement a traditional lecture-based class is that students may perversely feel incentivized to skip more lectures. Holbrook and Dupont [36] examined students' perceptions of the usefulness of online videos that combined audio with static imagery of PowerPoint® slides. Students in an introductory 100-level class and an advanced 400-level class were surveyed about their use of the videos. The survey asked about the number of videos used, how they were used, how helpful they were perceived to be, and whether it influenced decisions to skip class. The self-reported usage levels were the same across the two groups of students and most students indicated that the videos were very or extremely helpful. The main difference between the groups was in the decision to skip lectures. The more advanced students reported that the access was less of an influence to miss class, while the introductory students reported it was a greater influence. Wells et al. [37] examined the use of short 10–15 minute video tutorials to supplement in-class lectures about computer programming. Surveys measured students' satisfaction over several semesters. After experimenting with different policies to ensure that students used the videos before completing assignments, a total of 87% reported using the videos and finding them helpful. Less positively, the study found that the in-class lectures were correspondingly rated less useful and attendance dropped.

Lonn and Teasley [38] examined college students' attitudes and perceptions of podcasts used to supplement in-class lectures. This was done by surveying students and instructors who had experienced using podcasts via iTunes University®. Students reported using podcasts mainly for reviewing material already observed in-class and tended to use them just prior to exams. Interestingly, the podcasts were mainly accessed by computer instead of using portable mp3 players such as iPods®. Walls et al. [39] surveyed students in two classes who used either supplemental podcasts or repetitions of lectures. Students indicated that they generally found more benefit in the repetitive podcast lectures than in the supplemental materials. Again, the single most frequent method for consuming the podcasts was via the computer rather than true "m-learning" with mobile devices. Bolliger et al. [40] examined whether podcasting had an effect on student motivation when used within online courses. Over 300 students who had enrolled in 14 different online courses were surveyed after having a chance to sample a set of podcasts. Overall, the students reported feeling comfortable with the podcasts and perceived them as helpful in learning. The organization and focus of the podcasted material was received positively. The findings indicated that shorter videos were viewed more positively. Longer podcasts of up to an hour involved too much downloading time and students reported a loss of attention. The more advanced the post-secondary student (graduate vs. senior), the more motivated the students were to use the podcasts.

In a 2009 study of engineering classroom lecture capture (LC) technology outcomes, Davis et al. [41] found results supportive of the general use of LC in an engineering classroom, capturing full 60 minute lectures for students throughout the duration of the course. In this study, a traditional, face-to-face course showed increasing student usage of LC material throughout the term in different course sections, as well as qualitative feedback from students indicating heightened understanding of course content from the presence of these captured videos. Particularly interesting was the affirmation of self-motivated learning, in that "students saw revision and reinforcement of learning as key benefits of accessing captured materials" [41, p. 9]. The authors detailed that students would follow along with the professor's handwritten problems, pause to solve a problem, and then play the solution to determine their technique as correct or incorrect.

The preceding studies delved into the types of content provided (audio, audio plus video), length of videos, and began the exploration into the utility perceived by students with these supplemental content modules. However, the piece missing from literature at this point is a wrapper that ties student performance directly into use of these modules—in other words, aids students in using these resources at the prescribed time, in order to assist them with persistence across content being learned, and ultimately, across completion of the class in general.

3.3 Content modules expanded

Kay and Kletskin [42] examined the use of problem-based downloadable videos to teach first year Calculus. The videos ranged in length from 2.75 minutes to almost 15 minutes with an average length of just over 7.5 minutes. Each video featured a detailed problem being solved by the instructor and then a similar problem to be solved by the student. The videos automatically paused to allow the students to work on the practice problem until they were ready to advance to see the problem solution. Students were surveyed to assess their use and perceptions about the videos. A group of 195 students reported using the videos, and most felt they benefited by doing so with 87% reporting gains in learning. Carver and Howard discussed the creation of extensive learning materials to support the teaching of electrical engineering, including audios, videos, graphic files, lecture slideshows, and past student papers [43]. Students were surveyed to determine what resources they used and how valuable they found the resources to be. The survey responses were positive, and the ratings for each type of multimedia learning support varied according to students' learning preferences. The one negative finding was that some students felt overwhelmed and confused by the array of resources and unsure of how to choose a strategy for using them. Another study used lecture capture streaming videos to supplement regular lectures in an introductory programming course for information technology students [44]. Student surveys found high satisfaction levels, a sense of greater learning, and reported reductions in the required effort to complete homework. The instructors also reported that it was easier to transition between semesters since much of the material was reusable and fewer students requested additional learning assistance outside of class.

Kaw et al. [45] developed web-based learning modules to teach numerical methods using an approach that presented the core conceptual material and supplemented it with interactive problem simulations customized to the individual's choice of computational software. The modules were found to be effective in increasing student satisfaction and academic performance, which was also supported in later similar research by Lowerison, Tamim, and colleagues [46, 47] in which students tended to view the technology as positive and valuable, but did not always feel that the faculty had integrated the technology as a truly transformative tool or used it in the best way to be helpful to students. Lau and Mak [48] developed and tested an interactive multimedia e-learning system (IMELS) composed of multiple modules that provided introductory videos of material, references to online resources, and case problems for students to work through. Student surveys indicated that the IMELS stimulated their interest in learning more about the subject, helped them better integrate their knowledge, and was a positive teaching tool. Yao et al. [49] employed a multilevel interactive, web-based curriculum to teach students about non-traditional manufacturing processing that relied on a series of multimedia elements, including short videos and a virtual reality modeling language. Anderson et al. [50] used computer-based instruction (CBI) modules integrated with an introductory thermodynamics textbook. The modules were provided on a CD-ROM and incorporated interactive exercises, feedback responses, simulation, and modeling. The course was structured to specifically involve active learning exercises using the CBI modules and students' use was audited. Students were found to be using the materials as intended and test performance was generally positive. A subsequent study found that students actively engaged in the learning process but many used only very simple cognitive strategies [51]. De Sande [52] tested the effectiveness of a computer-based training tool which used an automated system of generating problems. Students were able to independently take self-assessment tests and receive automatic feedback. A set of 19 students who used the tool during the course was compared to a control set of 17 students in the same course. The mean grade of the students using the CBT tool was higher than that of the control group and likewise the standard deviation of their grades was lower. Both the difference in means and standard deviation were found to be statistically significant, indicating a positive impact of the active learning materials from the CD-ROM.

Sullivan et al. conducted an experiment of two web-based learning supplement approaches [53]. The two learning approaches were tested in separate semesters. Both tests included a single instructor teaching one treatment section and one control section. One treatment was requiring team projects based on realistic industry problem case studies posted online. The second treatment was creating a virtual classroom with online course modules, practice assessment quizzes, and some administrative support tools, along with access to the industry problem case studies. The treatment section using the industry-based projects performed significantly better than the control group. There was no statistically significant difference between the treatment section with the online course modules, quizzes, etc. and the control section. In fact, the web-based experimental group actually performed at a lower level. The web-based tools were available on an open-access website and no tracking was available to identify whether, when, or how often individual students used them.

Rae and Samuels [54] reviewed a series of analyses of virtual learning environments (VLEs) and concluded that a well-designed program of student self-study with frequent testing could positively impact mathematics instruction. Lai et al. [55] examined potential factors to determine which could be used to predict whether undergraduate students would choose to use learning technology. The data was gathered via an online survey and used to assess students' attitudes about: using technology, technology usefulness, compatibility with education, encouragement from peers and instructors, and the students' sense of computer self-efficacy. Peer and instructor support was found to be a significant factor. Also, students needed to see that using the technology was related to better educational outcomes. Lawton et al. [56] examined the incorporation of online supplemental material used for training courses at The Boeing Company with an LMS, where the students evaluated were Boeing employees. A control course that was taught online with summative assessment and limited learner feedback was compared to a treatment course. The treatment course was specifically designed with short, student-directed animated videos. Formative assessment was used and learners were offered opportunities for self-reflection on their learning. Pre- and post-tests were administered to see how well the course material was transferred to the students. During the experimental phase, the 21 students in the treatment course achieved higher post-test scores than the 18 students in the control course. Bhowmick et al. [57] examined a range of multimedia tools for asynchronous online learning. They found that the type of multimedia employed was not critical for performance on simple tasks. However, when the tasks increased in complexity, the type of multimedia became much more important. The most useful combination of multimedia for complicated learning tasks was text synchronized with audio and video.

In that vein, Lawton et al. [56] investigated across a control and experimental course situation the learning outcomes of students presented with engineering content through videos and embedded quizzing functions. Outcomes of this research, gauged only by comparing pre-test and post-test data at the beginning and end of terms for control and experimental participants, indicated that the students' final performance as a measure of success was higher in the experimental condition than in the control condition by an average of 5.50 points on post-test scores. The Lawton et al. study provides a strong foundation for useful comparison with the present study, as a number of similar instructional design components were used. In contrast, however, analysis of student outcomes from only a pre- and post-test analysis does not capture the full array of potential data that may show utility in these applied learning modules used in the present study.

3.4 Challenges in assessing e-learning modules' utility

In summary, the consensus of the prior research across the broad course formats of online, hybrid, and face-to-face with course module supplements is that web-based, multimedia learning tools can be effective in stimulating active learning when implemented appropriately. Further, the use of these e-learning modules is associated with higher student satisfaction rates in these courses and in some outcomes, with higher final assessment scores. One concern from these studies, however, is that many of the studies examining e-learning tools relied on sophisticated virtual and computer-based learning systems developed through large scale institutional resources, funded research, or commercial textbook publishers. These resources are not available to every instructor of STEM coursework in the higher education disciplines, so instructors may instead seek readily available, institution-wide resources to serve these same student support functions. Creating short audio or enhanced audio/visual learning tools, posting reference reading material, and designing automated practice quizzes to present and assess learning of core concepts is relatively simple with the array of media software currently available in both freeware/shareware or at small costs to individuals/institutions.

Assessing the utility of supplemental learning materials from prior research is complicated by methods of varying data collection that generally use less reliable measures of student self-reported use patterns and levels of overall satisfaction, as noted in the Lawton et al. (2012) study with limited outcome comparisons between solely pre- and post-tests. Previous studies' methodologies have not examined extensively beyond measures of student self-evaluation how performance (grade) outcomes may relate to the implementation of these tools. It is at this point that the current study attempts to evaluate whether these expanded e-learning modules have sufficient benefit through highly detailed quantitative evaluations throughout the term of the course into the students' learning outcomes. Further, the current research was conducted to examine actual use of online learning materials and likewise sought to address missing quantitative measures that target improved student learning outcomes, through capturing exam grades with course outcomes, alongside traditional evaluation methods such as students' perceptions of the e-learning modules. Lastly, this study examines the possibility of using the current LMS's automated functionalities to prescribe micro-learning assignments to target weak spots in student learning through an easily manageable interface akin to a learning dashboard [23], yielding increased student retention of knowledge (micro-retention of content), yielding overall retention of the student in the course, the major, and the STEM discipline itself, in turn.

4. Methodology

4.1 Background

The University of Alabama in Huntsville (UAH) is a mid-sized public research institution in the southeastern portion of the U.S. One of the introductory engineering courses required of most engineering undergraduates as a prerequisite for their senior design class is engineering economic analysis. Engineering economy is taught as a service course by the Industrial and Systems Engineering and Engineering Management Department. It is taught year round with an annual enrollment of approximately 400 students across 3–4 sections each of the full semesters and 1–2 sections during the summer. The only prerequisite for the course is sophomore standing, but most students are in their junior year. It is frequently taken by engineering students who have recently transferred in from two-year community college programs, because the lack of other prerequisites makes it an easy way to fill out a course registration schedule. The course has traditionally had a bimodal distribution of grades comprising two roughly normal distributions with different means. A portion of the students generally perform relatively well with a mean exam average of between 80 and 90%. Another portion of the students struggle with the material, the pace of college, and/or external commitments and have a much lower exam average. The percentage of students who did not achieve a successful completion with a C or better has fluctuated around 20% in the last four years. Research was conducted to identify factors that significantly predict success or failure, and proactive interventions were sought.

4.2 Technology applications

In 2010 the course instructors began employing automated, online assessment surveys administered through the ANGEL™ LMS [58] as a means of allowing students to submit their homework answers. Students were assigned problems to work offline and then given access to an assessment that posed multiple choice questions about the problems. The immediate advantage of this approach was that students received immediate feedback of which answers were incorrect and there was no delay in waiting for a grade. Knight et al. [59] used detailed data from the students' homework results, LMS system utilization, a background survey administered via the LMS, and prior academic records to predict students' exam performance and identify students at risk of poor performance in time to offer assistance. This led to the decision to develop supportive interventions, termed "prescribed interventions", for students to help them in preparing for exams or correcting misunderstandings of core conceptual material.

UAH offers both undergraduate as well as graduate coursework via Distance Learning (online learning), where lecture capture (LC) technologies allow students unable to attend in person to receive the lecture asynchronously by watching streaming video via a high speed internet connection. The LC option available for students includes the synchronized image displayed of a computer alongside the video and audio of the instructor as he/she works through the lecture, solves example problems using handwritten ink annotations shown on screen, and engages in interactive discussion with the class. UAH used the DL software platform Mediasite™ [60] as its LC provider until the end of 2013 when it switched to Panopto™ [61]. Figure 1 depicts an example of a student watching a Mediasite LC video by computer.

The asynchronous LC videos can be paused, rewound, or advanced to the specific content a student most needs to see and may be viewed an indefinite number of times per student user. Figure 2 shows an enlarged example of an instructor's anno-

Fig. 1. Lecture capture example featuring instructor's image and computer screen.

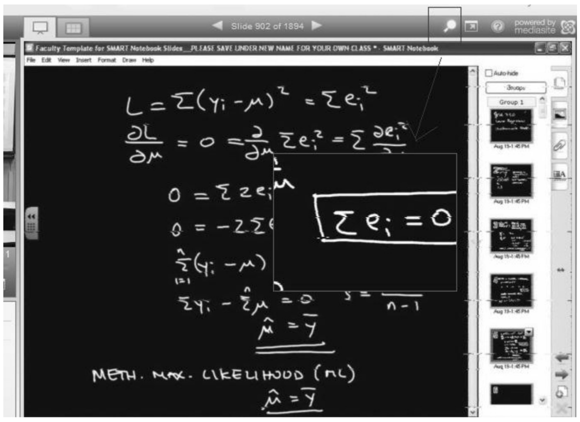

Fig. 2. Example of the image capture from an instructor's computer showing *Smartboard* sympodium annotations added during the lecture.

tated notes captured from the computer and synchronized to the lecture audio. The web-based access is available whenever the student chooses to use it and the computer from which the student views the content will store the last-played time on each video for up to ten videos per student, allowing easy re-access for students needing to review content multiple times. At the time, undergraduate students were not normally permitted to enroll in DL classes at this university, but these resources had been used periodically to pre-or post-record a lecture when scheduling conflicts or illness arose with an instructor, and for special supplemental lecture exercises, such as the e-learning modules used in this study.

4.3 Experimental application

The available DL infrastructure combined with the prior experience of using an LMS to distribute assignments, lecture notes, study materials, and collect homework led to the decision to experiment with constructing online ML modules that students could use to supplement in their class learning. Both the ANGEL LMS and Mediasite provide extensive tracking capability of individual student interaction with the systems and use of the content. This meant that a greater level of detailed data was available for collection and analysis than is generally obtainable through posted audio/video content. While some systems can identify that an individual student clicked on a link to access a multimedia resource, it's not always possible to tell if the audio/video content was then played to completion. Content posted on open websites normally cannot be tracked to identify individual students' access and use to the same extent that an authentication-based system with data analytics, such as ANGEL and Mediasite enable.

In 2013, a set of 12 short (18 minutes on average) focused video micro-lectures (ML), were recorded. The topics were chosen from content areas previously identified as points of concern in this particular course. They included nominal vs. effective interest rates; interest factor notation; deferred annuity and gradient cash flows; conducting economic analyses using net present worth, net annual worth, benefit/cost ratio analysis, rate of return analysis, and payback period analysis; choosing between mutually exclusive alternatives with the same lifespan; choosing between mutually exclusive alternatives with different lifespans; depreciation methods; and after tax cash flow methods. Each micro-learning module focused on a different topic and consisted of background reading materials, an ML video, a document with the ML's accompanying PowerPoint slides, and practice quiz material. For each micro-learning module, students were advised to review the background reference material, watch the ML video while accessing the ML PowerPoint slide document, try the practice quiz, and repeat as needed until they consistently answered the questions correctly. However, students were free to choose a different learning pathway option by picking and choosing which of the module materials would be used and in what sequence. Figure 3 depicts the recommended learning pathway.

The MLs contained video and audio of the instructor as she worked through discussion of the concepts and example problems, including real-time ink annotations denoting problem solving strategies. The graphics were kept very simple with modest amounts of text and depictions of cash flow diagrams or cash flow tables. While imagery of the professor speaking was provided, most of the video image consisted of the synchronized capture of the *Smartboard* sympodium as the *PowerPoint* slides were displayed and electronic ink annotations were made. Figure 4 shows an example of an ML streaming video image with annotated notes added to the PowerPoint slide. Students can see the most recent screen captures of the computer's *Smartboard* sympodium that have just been played and those just upcoming, while the synchronized audio–video image of the instructor is displayed to the side. Ranging from 5 to 35 minutes depending on the complexity of the topic, the MLs enable students to

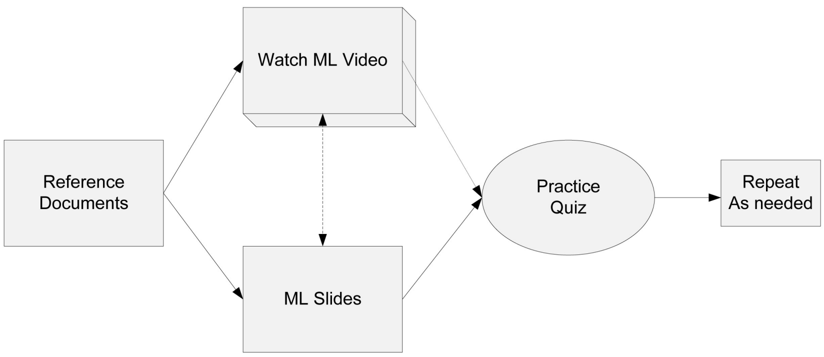

Fig. 3. Micro-learning module learning pathway options.

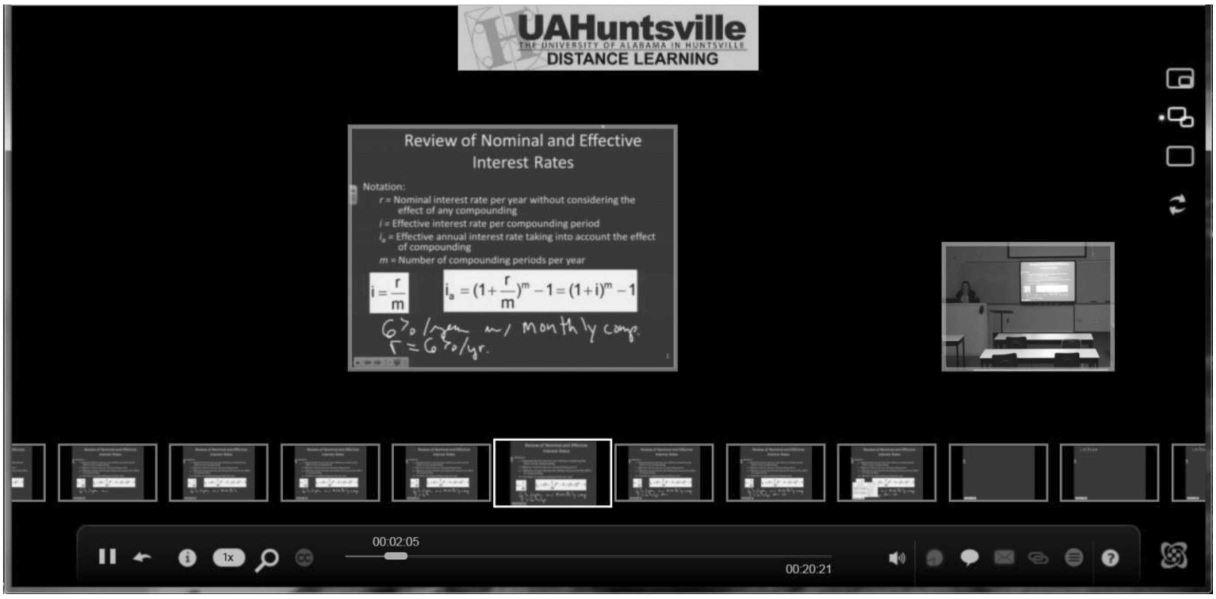

Fig. 4. Screen capture of an ML video.

log in at a time and place of their choosing to refresh their memory of lectures, check their understanding of the concepts, and correct any initial misunderstandings. The MLs were also enabled for mobile device viewing, to increase the viewing likelihood. The data analytics from the Mediasite software permit researchers to determine exactly which students logged in to see each video, when the videos were watched, how often they were watched, and what percentage of each video individual students watched. Access to the LMS from mobile devices had already been available prior to the micro-learning modules' creation. Two online automated assessments were created as practice quizzes for the material that students could repeatedly take to prepare for exams. The combination of supplemental learning materials was meant to accommodate a broad range of students' preferred learning styles. The expectation was that students doing homework or reviewing for an exam would find the online modules a helpful, time-efficient way of making sure they understood the concepts.

The ML content was introduced on an experimental basis with one section of the target course midway through the Spring 2013 semester. The students' responses were generally favorable with several students that had struggled through earlier points in the class saying that watching them was a good way to catch up on the concepts before an exam. A small experiment was designed for use with two sections of the course in Summer 2013, taught by adjunct professors. This experiment focused on evaluating the students on their knowledge of the core concept of nominal vs. effective interest rates. Students were directed to review the associated ML if they had difficulty with these concepts and did not score above a particular minimal concept knowledge level on prior exams. The results from this initial evaluation with the MLs as remediation tools indicated that the students who chose to use MLs generally improved their overall content knowledge as a result of reviewing the content therein, but the samples were too small to draw definitive conclusions. It was however sufficient to make the micro-learning modules available to students in the graduate engineering economic analysis course as well as doctoral students preparing for their comprehensive exam. The anecdotal reviews of the graduate students were quite positive. Despite promising initial results, their effectiveness needed to be tested before investing resources to expand their use. Among the questions to be resolved were whether demonstrating the MLs and pointing out the benefits of using them would be sufficient to motivate students to use them or whether a more sustained effort would be required to encourage students to make use of them. Another question was would students who had difficulty with the core concepts and were prescriptively instructed to use the modules act on this, and if they did so, would they experience improved learning?

The research hypotheses for this study were as follows.

1. Students in sections where the MLs and practice quizzes are more heavily promoted and initially required will continue to utilize them at a higher rate in the latter phase of the class than students in sections where they are not initially required.

2. Students that use the MLs and practice quizzes will have better exam scores and overall course score outcomes than students who do not use them when controlling for prior performance using the students' cumulative grade point average (GPA) as of the start of the semester.
3. Students who are advised to review specific MLs and do so will have better subsequent exam scores on core conceptual questions and overall course score outcomes than students who do not follow the advice when controlling for prior performance using the students' prior GPA.
4. Students as a group will have a higher average course score outcome when taught using MLs vs. not using them when controlling for the instructor and prior student performance.

4.4 Experimental procedures and results

Based upon the positive outcomes from the initial pilot with the MLs as a learning tool, a full-scale experiment was designed for the Fall 2013 semester in three sections of the target class, which were led by instructors who had each previously taught the class and had integrated the MLs to some degree. Prior research had indicated that transfer student status and gender were significant risk factors for an unsuccessful course outcome [62]. An initial, highly detailed student survey was administered across all sections of the course to collect background information about the students, including demographics, content preparation, enrollment status, current level of school/work/family demands, and academic goals and expectations for the course. Additional data including gender, race/ethnicity, age, and cumulative prior GPA were also gathered from the university's student record database.

Course material was provided via: handouts posted on the LMS; sets of guided note-style lecture slides via PowerPoint; lecture example problems; solved practice problems; and some Excel^{TM} spreadsheet model solutions for example problems, all made available within the university's LMS. Access by each individual student to each element within this content was tracked and evaluated with analytics from the LMS. Three in-class exams per section with an optional comprehensive Final Exam were instituted across all sections of this course. The Final Exam also served as a makeup exam if a student had an excused absence from one of the earlier exams. The exams included a mix of quantitative problem solving, conceptual short answer questions, and multiple choice questions. The exams were closed book and closed notes with an official formula sheet and relevant tabulated interest rate factor sheets issued to the students. Similar course coverage schedules were planned to ensure that the three sections were consistent in both content and timing. However, each instructor had different emphases on the particular content, and the sections taught by the adjunct instructors were not able to match the content tested on each exam to the test section. Due to the lack of compatibility among instructional content and pacing, it was ultimately decided that close synchronization was not feasible for evaluation of this experimental model. To ensure that a control was available, instead the sections taught by the adjunct instructors were used to test the process of implementing the micro-learning modules on a larger scale, but not to serve as controls on the test section. Controls were designated as two sections previously taught by the test section instructor using the same textbook edition, the same course coverage schedule, and the same material emphases.

Section 1 was taught prior to the development of the micro-learning modules and had no exposure to them. Section 2 was taught in Spring 2013 and had no exposure to the micro-learning modules before Exam 2. Section 3, the test section, was taught in Fall 2013 and used the micro-learning modules during the course. Table 1 summarizes the breakdown of the students in each section by prior performance level, transfer student status, gender, and race/ethnicity. The prior academic performance was assessed using a binary classification for the prior GPA between higher and lower. The students were categorized by having a cumulative prior GPA $\geq$ 3.0 or < 3.0. This value was the approximate median cumulative prior GPA for all three sections. Table 2 depicts the breakdown of course outcomes across the three sections where a successful outcome

Table 1. Student breakdown by prior GPA and demographic categories by section

		Transfer status		Gender		Race/Ethnicity			
Section	**Prior GPA level**	**"Native"**	**Transfer**	**Male**	**Female**	**White**	**Other**	**Sub-Total**	**Total**
1 control	H	26	18	34	10	40	4	44	88
	L	17	27	31	13	29	15	44	
2 control	H	12	12	19	5	16	8	24	40
	L	4	12	15	1	13	3	16	
3 test	H	8	18	23	3	23	3	26	38
	L	3	9	11	1	11	1	12	

Table 2. Student breakdown by prior GPA and course outcome by section

Section	Prior GPA level	Course outcome: Unsuccessful (D/F/W)	Course outcome: Successful (A/B/C)	Total
1 control	H	2	42	44
	L	22	22	44
2 control	H	0	24	24
	L	8	8	16
3 test	H	4	22	26
	L	4	8	12

is earning an A, B, or C and an unsuccessful outcome is withdrawing or earning a D/F. A comparison of the sections by mean prior GPA showed Section 1 had a slightly higher mean and median cumulative prior GPA, but there were no significant differences between semesters.

The test section assigned the students to watch a single specific ML prior to Exam 1 in order to ensure the students were familiar with logging into Mediasite and able to watch the videos. Students were free to watch any of the MLs at that time, but were only required to watch the one that briefed them on using interest factor notation to solve problems. These students were then assigned to complete an automated, randomized online quiz heavily focusing on nominal vs. effective interest rates. If a student did not score 80% or higher on the first attempt, they were instructed to watch the nominal vs. effective interest rate ML, review the associated handouts, and repeat the quiz until successfully completing it with at least 8 of 10 questions correct. The students were given four days to complete this assignment prior to Exam 1, and they were reminded with automated e-mail messages through the LMS, if they had not yet completed the quiz at the minimal acceptable pass level.

Students in the two adjunct-taught sections were informed four days before Exam 1 that the MLs were available, instructed how to access them, and encouraged to practice with the automated, randomized online quiz. Utilization of the practice quiz and MLs was not mandatory for the students in the other two sections. No reminder emails were sent in these sections. The test section's Exam 1 included a question similar to the online practice quiz written to test the students' grasp of nominal vs. effective interest rates and their ability to incorporate this information into their problem solving. As exams were graded, students exhibiting difficulty in demonstrating their mastery of this subject were flagged for follow up attention. These students prescriptively received individual instructions to review the content and use the practice quiz to ensure they learn the concepts. A second question was included in Exam 2 to assess whether the students had overcome any earlier conceptual deficit. This followed the pattern used in previous semesters to determine whether core concepts including use of nominal vs. effective interest rates were being learned. Students who performed below a level of 70% on Exam 1 were advised of strategies and tools for addressing the problem and suggested to make use of them. Individual student scores for each question on each exam across all three semesters were recorded, allowing comparison of student performance on specific content across the semesters. The students' performance through Exam 3, the optional Final exam, and overall course outcomes were tracked to determine if this e-learning content as a prescriptive intervention was successful in aiding students' content knowledge, as well as in improving the percentage of students successfully completing the course.

As expected, the sections where students were required to watch a single ML (interest factor notation) and use one e-learning module (nominal vs. effective interest rates) saw higher utilization of the other micro-learning modules throughout the course. Table 3 shows the utilization figures across the three sections. The two adjunct-taught sections where the e-learning modules were made available but not heavily promoted were used by approximately 20% of the students with an even distribution between students who were performing well vs. those who were struggling. The use of the online assessment quiz within these sections also varied. One section had only 20% of the students attempt the quiz, and all but one of those students earned a 70 or above on their first attempt. In the other section a full 50% of the students attempted the quiz, with five scoring 80 or above on their first attempt, 3 scoring 70, and the rest scoring 60 or lower. Only three students who scored below an 80 decided not to repeat the quiz. Several students repeated it multiple times until achieving a satisfactory score. In the test section, utilization was much higher with 30 of 38 students watching the ML and 34 utilizing the online assessment quiz within that e-learning module. Only one student who earned less than 80 on the first attempt failed to make subsequent attempts.

Pearson's chi-square tests were conducted to determine if the distribution of outcomes for various variables when controlling for Prior GPA varied between sections. For Section 1, Prior GPA was significantly associated with the binary Exam 1 score (>70 or not) with a resulting p-value of approximately 0. For Section 3, Prior GPA was not significantly associated with this variable. Prior GPA was significantly associated with the binary Exam 2 score (>70 or not) with a resulting p-value of

Table 3. Summary of micro-learning module usage

Fall 2013 section	Number of students enrolled	No. of students who watched ML videos	No. of students who attempted practice quizzes	No. of students who scored $\geq$ 70 on first quiz attempt
Adjunct 1	47	2	21	8
Adjunct 2	45	1	10	5
Test	38	30	34	17

approximately 0 for Section 1. It was not significant for Section 3. Prior GPA was also significantly associated with the binary Course Outcome variable for Sections 1 and 2 (*p*-value of approximately 0), but it was not significant for Section 3. The volume of data was not sufficient to examine demographic effects of transfer status, gender, or race/ethnicity.

5. Discussion

The first research hypothesis was found to be supported. Once students became familiar with finding the online micro-learning modules and accessing the MLs through the Mediasite lecture capture system, the frequency of their usage increased. There was a much sharper increase in the number of students in Section 3 watching multiple MLs than there had been in the Section 2 control. The two adjunct-taught sections exhibited far fewer students watching MLs or using the online assessments than the sections taught by the lead author of this study, a full time faculty member who developed the MLs.

The second research hypothesis was not fully supported. The distribution of outcomes between successful (A/B/C) vs. unsuccessful (D/F/W) was more favorable in Section 2, which used MLs for half of the semester, as well as in Section 3, which used MLs and automated practice quizzes, as compared to the Section 1 control. However, this difference was not statistically significant when controlling for Prior GPA across sections.

There was insufficient data to test the third research hypothesis since almost all the students in Section 3 that were prescriptively assigned to use the MLs to address deficits in conceptual understanding did so. No conclusions could be drawn about the outcomes of the students who followed the instructions vs. those that did not. The three students who were advised to use the MLs but did not do so managed to address the deficits in other ways and successfully completed the course without the use of the prescribed ML learning modules.

The fourth research hypothesis was not proven. The average course score improved from Section 1 to Section 2 and from Section 1 to Section 3. The average course scores of Sections 2 and 3 were very close, but Section 2 actually had a slightly higher mean and median. The difference was not statistically significant whether controlling for Prior GPA or not. Overall, the results in Sections 2 and 3 suggest that the micro-learning modules may be helpful for some students that make use of them, but that further study with larger samples is needed to confirm or disprove their level of effectiveness.

Several factors may have affected the students' willingness to use the e-learning modules that were offered during the course of these experimental procedures. The online assessment quiz, the ML notes, and associated handouts were available through the ANGEL LMS, which the students were accustomed to logging into on a regular basis. The Mediasite server was not integrated with the LMS and students had a separate login to reach the ML videos, which may have served as a discouragement for students logging in, since two separate logins were required. The undergraduate students during this period of time at the university did not use Mediasite for coursework and were less familiar with the system on the whole. This lack of access through a single sign on (SSO) was resolved after the Fall 2013 semester, with the transition to the new lecture capture software system, *Panopto*, in January 2014 that is integrated within the LMS and offers SSO convenience for both students and faculty.

A second factor of potential impact that may have minimized the students' willingness to use the available e-learning resources was the length of the micro-learning videos. While the target length was 5–10 minutes, several of the videos were longer, including the nominal and effective interest rate ML. With more students opting for mobile viewing platforms, even a video of 10 minutes is disfavored. This is being addressed by plans to create several shorter videos to further break down the topics into smaller conceptual doses. For example, the nominal vs. effective interest rates concept material would be subdivided into MLs on nominal interest rates, effective interest rates per compounding period, and effective interest rates per cash flow period. A broader test of more of the e-earning modules is being designed. Further, the use of the mobile learning apps is readily available through the new lecture capture system on all iOS (Apple) mobile devices through a free app available to students. As well, functionality on mobile devices (tablets, cellular phones, etc.) formatted for the Android OS are desired for our users, as a large proportion of students on our campus and the majority of users (81%) across the world [63, 64] use the Android operating system. The Android OS is not currently fully supported in our newly implemented LC platform but this enhancement is scheduled to occur in the near future and we anticipate that it may play a significant role in user adoption of content consumption in our learning modules. The ease with which students may have access to and review content may promote their likelihood of making use of these modules, therefore making all content accessible across iOS and Android mobile devices will be an important factor in future applications of technology in this study.

Generally, the findings are consistent with the prior literature in several key respects. Students that made use of the modules reported feeling that they were helpful and their inclusion in the course was appreciated. As Bolliger et al. found, shorter videos were more apt to be used than the longer ones. Students who had previously performed well tended to be more responsive in using the MLs as suggested before exams as Wells, Barry, and Spence had found. Carver and Howard reported students indicated that they felt somewhat overwhelmed by the array of resources and, even with far less content and variations in media, this was also observed. The findings were not consistent with respect to demonstrating improved learning and academic performance as had been reported by Kaw et al., Lowerison et al., Tamim et al., Lawton et al., and De Sande. The primary limitation of the research was that there was insufficient experimental data to test whether teaching with MLs produced better learning or if students that previously performed poorly and subsequently used the modules would have better exam performances than those who did not use the modules.

6. Conclusions and future work

Future studies will incorporate the new lecture capture system's functionality alongside the benefits of the SSO to the LMS with the use of the e-learning tools as well as the shortened ML videos for the micro-learning modules. Additionally, work with faculty members teaching the same course across different sections in a semester will be more tightly integrated to have comparable examinations, which will synchronize the data collection and provide greater strength to the data pool. Standardizing the intent to require the use of micro-learning supplemental content modules across all sections offered regardless of faculty rank will also strengthen the solidarity of the experimental design and allow for larger pools of comparable data to be evaluated. It will also allow for greater examination of the potential effects of the demographic, experiential, and attitudinal data that were included in the study design. Although this particular study focused on the topic of engineering economic analysis, which is of broad interest to other engineering disciplines, the premise of identifying core concepts that are commonly misunderstood and designing multimedia learning aids using the micro-learning module approach is widely applicable to other disciplines and courses. For example, probability and statistics is another core course for all engineering undergraduates, and instructors working without extensive online resources from their university or textbook publisher could gradually construct suitable modules.

The goals of this research project to aid students needing assistance with core concepts in engineering economic analysis were met through the development of key video content recorded as MLs, as well as the implementation of extensive student monitoring and e-learning modules. Students who received explicit directives with required expectations for content engagement did indeed show improvements when using the e-learning modules provided, and while a small sample initially, these preliminary results provide positive direction for future research in this arena. While not all the hypotheses were supported with the data collected at this early stage of research, it is anticipated that methodology and technological improvements will yield more conclusive findings in further research. The authors hope to ultimately devise a useful methodology that may be implemented beyond the current university environment that may be expanded into other engineering disciplines as well as related STEM Higher Education disciplines.

References

1. M. D. Garrett and M. C. Poock, Resource allocation and management strategies in times of fiscal constraint and their impact on students, *College Student Journal*, **45**(4), 2011, pp. 882–890.
2. R. J. Hansen, W. S. McClure and S. Parkes, Dangerous opportunities: strategic implications of the global financial crisis, *Continuing Higher Education Review*, **73**, 2009, pp. 184–193.
3. P. Skomsvold, A. W. Radford and L. Berkner, *Six-year Attainment, Persistence, Transfer, Retention, and Withdrawal Rates of Students who Began Postsecondary Education in 2003–04*, National Center for Education Statistics, Washington, D.C., 2011, p. 381.
4. J. Offenstein, C. Moore and N. Shulock, *Advancing by Degrees: A Framework for Increasing College Completion*, Institute for Higher Education Leadership & Policy and The Education Trust, Sacramento, CA, 2010, p. 25.
5. B. A. Weisbrod and E. D. Asch, The truth about the ''crisis'' in higher education finance, *Change*, **42**(1), 2010, pp. 23–29.

6. A. Dunbar, D. Hossler, D. Shapiro, J. Chen, S. Martin, V. Torres, D. Zerquera and M. Ziskin, *National Postsecondary Enrollment Trends: Before, During, and After the Great Recession. Signature [TM] Report 1*, in *National Student Clearinghouse*, 2011, p. 73.
7. A. C. Logue, Tough conversations talking about student debt- and default-across the campus, *University Business*, **14**(9), 2011, pp. 44–48.
8. Federal Reserve Bank of New York, *Quarterly Report on Household Debt and Credit—Q1 2014*, Federal Reserve Bank of New York, New York, NY, 2014, p. 31.
9. C. M. Mullin, *It's a Matter of Time: Low-Income Students and Community Colleges. AACC Policy Brief 2012–02PBL*, American Association of Community Colleges, 2012, p. 13.
10. M. Parry, Students get savvier about texbook buying, *Chronicle of Higher Education*, **59**(21), 2013, pp. A22–A23.
11. T. Berry, C. Lori, H. Nancy and S. Kevin, An exploratory analysis of textbook usage and study habits: misperceptions and barriers to success, *College Teaching*, **59**(1), 2011, pp. 31–39.
12. R. M. Felder and L. K. Silverman, Learning and teaching styles in engineering education, *Engineering Education*, **78**(7), 1988, pp. 674–681.
13. R. M. Felder and R. Brent, Understanding student differences, *Journal of Engineering Education*, **94**(1), 2005, pp. 57–72.
14. P. Katsioloudis and T. D. Fantz, A comparative analysis of preferred learning and teaching styles for engineering, industrial, and technology education students and faculty, *Journal of Technology Education*, **23**(2), 2012, pp. 61–69.
15. M. C. Wittrock, Learning as a generative process, *Educational Psychologist*, **11**(2), 1974, pp. 87–95.
16. M. C. Wittrock, A generative model of mathematics learning, *Journal for Research in Mathematics Education*, **5**(4), 1974, pp. 181–196.
17. C. C. Bonwell and J. A. Eison, *Active Learning: Creating Excitement in the Classroom* in *1991 ASHE–ERIC Higher Education Reports* [e-book], Association for the Study of Higher Education, ERIC Clearinghouse on Higher Education, Washington D.C., George Washington University, Washington D.C. School of Education and Human Development, 1991, p. 121.
18. M. C. Wittrock, Teaching learner generative strategies for enhancing reading comprehension, *Theory into Practice*, **24**(2), 1985, pp. 123–126.
19. H. W. Lee, K. Y. Lim and B. L. Grabowski, Generative learning: principles and implications for making meaning, in J. Michael Spector et al., (Eds), *Handbook of Research on Educational Communications and Technology*, 3rd edn, Taylor & Francis, New York, NY, 2007, pp. 111–124.
20. L. S. Vygotsky, *Thought and Language*, MIT Press, Cambridge MA, USA, 1962.
21. L. S. Vygotsky, R. W. Rieber and M. J. Hall, The collected works of L. S. Vygotsky, Vol. 4: The history of the development of higher mental functions, *The Collected Works of L. S. Vygotsky*, Plenum Press, New York, NY, US, 1997, p. 294.
22. J. S. Bruner and R. Watson, *Child's Talk: Learning To Use Language* 1st edn, W.W. Norton, New York, 1983, p. 144.
23. K. Verbert, E. Duval, J. Klerkx, S. Govaerts and J. L. Santos, Learning analytics dashboard applications, *American Behavioral Scientist*, **57**(10), 2013, pp. 1500–1509.
24. R. E. Mayer, Multimedia aids to problem-solving transfer, *International Journal of Educational Research*, **31**(7), 1999, pp. 611–623.
25. R. E. Mayer, Incorporating motivation into multimedia learning, *Learning & Instruction*, **29**, 2014, pp. 171–173.
26. R. E. Mayer, *Multimedia Learning*, 2nd edn, Cambridge University Press, NY, 2009, p. 318.
27. R. E. Mayer and R. Moreno, Aids to computer-based multimedia learning, *Learning & Instruction*, **12**(1), 2002, pp. 107–119.
28. P. Chandler and J. Sweller, Cognitive load theory and the format of instruction, *Cognition and Instruction*, **8**(4), 1991, pp. 293–332.
29. J. Sweller, Cognitive load during problem solving: effects on learning, *Cognitive Science*, **12**(2), 1988, pp. 257–285.
30. J. Sweller, Cognitive load theory, learning difficulty, and instructional design, *Learning and Instruction*, **4**(4), 1994, pp. 295–312.
31. J. Sweller and P. Chandler, Why some material is difficult to learn, *Cognition and Instruction*, **12**(3), 1994, pp. 185–233.
32. J. Sweller, J. J. G. van Merrienboer and F. G. W. C. Paas, Cognitive architecture and instructional design, *Educational Psychology Review*, **10**(3), 1998, pp. 251–296.
33. J. Sweller, Instructional design in technical areas, *Australian Education Review*, Vol. 43, PCS Data Processing, Inc., NY, 1999, p. 168.
34. K. A. Austin, Multimedia learning: cognitive individual differences and display design techniques predict transfer learning with multimedia learning modules, *Computers & Education*, **53**(4), 2009, pp. 1339–1354.
35. A. Wong, W. Leahy, N. Marcus and J. Sweller, Cognitive load theory, the transient information effect and e-learning, *Learning and Instruction*, **22**(6), 2012, pp. 449–457.
36. J. Holbrook and C. Dupont, Making the decision to provide enhanced podcasts to post-secondary science students, *Journal of Science Education and Technology*, **20**(3), 2011, pp. 233–245.
37. J. Wells, R. M. Barry and A. Spence, Using video tutorials as a carrot-and-stick approach to learning, *IEEE Transactions on Education*, **55**(4), 2012, pp. 453–458.
38. S. Lonn and S. D. Teasley, Podcasting in higher education: what are the implications for teaching and learning?, *Internet & Higher Education*, **12**(2), 2009, pp. 88–92.
39. S. M. Walls, J. V. Kucsera, J. D. Walker, T. W. Acee, N. K. McVaugh and D. H. Robinson, Podcasting in education: are students as ready and eager as we think they are?, *Computers & Education*, **54**(2), 2010, pp. 371–378.
40. D. U. Bolliger, S. Supanakorn and C. Boggs, Impact of podcasting on student motivation in the online learning environment, *Computers & Education*, **55**(2), 2010, pp. 714–722.
41. S. Davis, A. Connolly and E. Linfield, Lecture capture: making the most of face-to-face learning, *Engineering Education*, **4**(2), 2009, pp. 4–13.
42. R. Kay and I. Kletskin, Evaluating the use of problem-based video podcasts to teach mathematics in higher education, *Computers & Education*, **59**(2), 2012, pp. 619–627.
43. C. A. Carver Jr. and R. A. Howard, Enhancing student learning through hypermedia courseware and incorporation of student learning, *IEEE Transactions on Education*, **42**(1), 1999, pp. 33–38.
44. J. Nicholson and D. B. Nicholson, A stream runs through IT: using streaming video to teach information technology, *Campus-Wide Information Systems*, **27**(1), 2010, pp. 17–24.
45. A. K. Kaw, G. H. Besterfield and J. Eison, Assessment of a web-enhanced course in numerical methods, *International Journal of Engineering Education*, **21**(4), 2005, pp. 712–722.
46. G. Lowerison, J. Sclater, R. F. Schmid and P. C. Abrami, Student perceived effectiveness of computer technology use in post-secondary classrooms, *Computers and Education*, **47**(4), 2006, pp. 465–489.
47. R. M. Tamim, G. Lowerison, R. F. Schmid, R. M. Bernard and P. C. Abrami, A multi-year investigation of the relationship between pedagogy, computer use and course effectiveness in postsecondary education, *Journal of Computing in Higher Education*, **23**(1), 2011, pp. 1–14.
48. H. Y. K. Lau and K. L. Mak, A configurable e-learning system for industrial engineering, *International Journal of Engineering Education*, **21**(2), 2005, pp. 262–276.
49. Y. L. Yao, G. J. Cheng, S. Feiner, Z. Wenwu, K. P. Rajurkar and R. Kovacevic, A web-based curriculum development on nontraditional manufacturing with interactive features, *International Journal of Engineering Education*, **21**(3), 2005, pp. 546–554.
50. E. E. Anderson, R. Taraban and M. P. Sharma, Implementing and assessing computer-based active learning materials in introductory thermodynamics, *International Journal of Engineering Education*, **21**(6), 2005, pp. 1168–1176.
51. R. Taraban, E. E. Anderson, A. DeFinis, A. G. Brown, A. Weigold and M. P. Sharma, First steps in understanding engineering students' growth of conceptual and procedural

knowledge in an interactive learning context, *Journal of Engineering Education*, **96**(1), 2007, pp. 57–68.
52. J. C. G. De Sande, Computer-based training tool for signals and systems exercises, *International Journal of Engineering Education*, **27**(5), 2011, pp. 1150–1157.
53. W. Sullivan, J. Terpenny and H. Singh, A virtual classroom experiment for teaching engineering economy, *The Engineering Economist*, **49**(4), 2004, pp. 279–306.
54. A. Rae and P. Samuels, Web-based personalised system of instruction: an effective approach for diverse cohorts with virtual learning environments?, *Computers & Education*, **57**(4), 2011, pp. 2423–2431.
55. C. Lai, Q. Wang and J. Lei, What factors predict undergraduate students' use of technology for learning? A case from Hong Kong, *Computers & Education*, **59**(2), 2012, pp. 569–579.
56. D. Lawton, N. Vye, J. Bransford, E. Sanders, M. Richey, D. French and R. Stephens, Online learning based on essential concepts and formative assessment, *Journal of Engineering Education*, **101**(2), 2012, pp. 244–287.
57. A. Bhowmick, M. T. Khasawneh, S. R. Bowling, A. K. Gramopadhye and B. J. Melloy, Evaluation of alternate multimedia for web-based asynchronous learning, *International Journal of Industrial Ergonomics*, **37**(7), 2007, pp. 615–629.
58. Blackboard Inc. *Blackboard Learn ANGEL edition*. 2014 [Last accessed 2014 June 26], http://www.blackboard.com/Platforms/Learn/ANGEL-Resources.aspx.
59. A. M. Knight, G. M. Nicholls and P. J. Componation, Measuring the effect of on-line homework procedures on student exam performance, in *American Society for Engineering Education*, American Society for Engineering Education, San Antonio, TX, 2012, pp. 1–18.
60. Sonic Foundry Inc. *Mediasite*, 2014, [Last accessed 2014 June 26], http://www.sonicfoundry.com/mediasite.
61. Panopto Inc. *Panopto*, 2014, [Last accessed 2014 June 26], http://panopto.com.
62. G. M. Nicholls, Analyzing time to student course withdrawal patterns for predictive modeling, in *American Society for Engineering Education Southeastern Regional Conference*, 2013, American Society for Engineering Education – Southeast Region, Cookeville, TN, pp. 1–8.
63. L. Mahapatra, What's the most popular mobile phone brand in your country?, *International Business Times News*, 2013, The International Business Times Inc.
64. V. Hernandez, Lack of large-display smartphones to sell is reason why iPhone market share is shrinking, while Android and Windows are expanding, in *International Business Times Australia*, 2013, The International Business Times Inc.

Gillian M. Nicholls is an Assistant Professor of Quantitative Methods at Southeast Missouri State University. Her research interests are in applying statistical analysis and optimization to persistence and retention in education; operations and supply chain management; economic analysis and decision making; and statistical modeling and applications. She holds a BS in Industrial Engineering (Lehigh University), Masters in Business Administration (Penn State University), MS in Industrial Engineering (University of Pittsburgh.), and Ph.D. in Industrial Engineering (University of Pittsburgh).

Sherri L. Restauri is the Director of State Authorization and Distance Learning for Academic Affairs and for the College of Engineering at The University of Alabama in Huntsville. Her current research includes the investigation into educational technology tools for enhanced student learning outcomes across the broad spectrum of face-to-face, hybrid, and online coursework opportunities. She holds a BS in Psychology (Jacksonville State University), MS in Psychology (Jacksonville State University), and Ph.D. in Educational and Developmental Psychology (Capella University).