Bringing Experiential Learning into the Online Classroom: A Mechanics of Materials Course Case Study

Dr. David Brian Dittenber, LeTourneau University

Dr. David Dittenber is an assistant professor of civil engineering at LeTourneau University in Longview, Texas. He earned his bachelor's degree in mechanical engineering at LeTourneau and spent a year teaching high school math and science. He then attended West Virginia University, where he earned his master's and doctoral degrees in civil engineering, with a research focus on the use of composite materials in infrastructure. Dr. Dittenber chose to return to his alma mater to teach, largely because of LeTourneau's reputation of being a hands-on, undergraduate-centric, teaching-focused engineering program.

Ms. Allyson Jo Ironside, Oregon State University

Ally Ironside is a recent graduate from LeTourneau University where she studied Water Resources in Civil Engineering. She is currently fusing her technical background with her passion for education in pursuing a doctoral degree in Civil Engineering while conducting research in Engineering Education at Oregon State University. Her research interests include the adoption of teaching best practices in engineering and the personal epistemology development of students.

Bringing Experiential Learning into the Online Classroom: A Mechanics of Materials Course Case Study

Abstract

An online Mechanics of Materials course offered in the summer of 2016 by LeTourneau University was designed to include several unique components intended to facilitate experiential learning in a manner more typically found in some traditional classroom-delivery courses. In addition to video lecture and example materials, course innovations aimed at achieving these outcomes included: a small project involving students' evaluation of mechanics principles in their surroundings with a peer review, an analysis of a case of historical importance in which a failure related to mechanics of materials occurred, and the delivery of a physical activity kit to each student filled with demonstration materials relevant to the concepts of the course. Student perceptions about the efficacy of the tools and projects at meeting the goal of increasing connections between course concepts and real world applications were collected through a brief survey of participating students. Based on the results of the survey, students appear to self-identify that both small projects and several of the materials available in the physical activity kit contributed positively to their connections between the course concepts and real world applications. Student feedback through free-response also included helpful recommendations, such as increased interaction opportunities between course participants and the replacement of written instructions with video demonstrations showing how to make the best use of the items in the physical kit.

Introduction

Online learning is a critical component of higher education in the United States. Allen et. al, operating on behalf of the Sloan Consortium and the Babson Survey Research Group, have been monitoring statistics of online education enrollment in the US and producing yearly reports on their findings for over a decade [1]. Per their most recent report, as of fall 2014, about 14% of all students in higher education in the US, or a total of over 2.8 million students, were taking exclusively distance education courses. A slightly higher number were taking some, but not all, of their higher education courses online. That amounts to a proportion higher than 1 out of 4 of students enrolled in higher education in the US who are taking at least one of their courses in a distance-learning format. Much of the growth in the number of students taking some or all online courses leading to these numbers has taken place at not-for-profit institutions since 2012, even as online enrollment at for-profit institutions has significantly decreased in the same time span [1]. One of the most relevant findings from these yearly surveys, however, is that engineering has shown a trend of being an outlier among other disciplines [2]. While most disciplines have exhibited steady growth in online enrollment, engineering has consistently proven to be the only discipline area with significantly lower online representation.

Online Engineering Education

Why has engineering, a discipline rooted in the principles of innovation and leveraging technology effectively, lagged so far behind the other fields of higher education in adopting distance learning? According to a 2010 report on the global state of engineering by UNESCO

[3], “the lack of qualified engineers and technicians is currently reported to be one of the principal obstacles to economic growth encountered by innovative firms in many industrialized and industrializing countries.” While the relative need for increased numbers of engineers in the workforce may vary from industry to industry and be an issue of debate, most engineering educators would at least agree that extending the methods and opportunities of engineering education to as many potential students as possible is a worthy pursuit. Further drivers for developing online engineering courses include the needs to fill under-populated classes, to extend offerings of over-populated classes, to provide flexibility for educators, to serve students operating on difficult schedules, to promote lifelong learning, to control costs, and to reach a broader population of learners [4]. Despite these motivating factors, the adoption of quality online courses and programs in engineering has been slow. The challenge, therefore, does not seem to be a lack of interest or viable market, but is instead a more complex mix of factors involving translating the material covered in engineering courses and the methods traditionally used to educate engineers to an online delivery.

This study examines some of these issues preventing more widespread online engineering education and presents the development and offering of an online mechanics of materials course as a case study. This course introduced several reasonably simple innovations to overcome some of the commonly feared shortcomings of offering engineering courses online, with the efficacy of these course components assessed through a student survey.

Maintaining Quality

Engineering already has a reputation of being one of the more difficult subjects students can select to study [4]. As compared to other programs, the conversion of engineering education to the online environment offers unique challenges. The basis in math and science, which are also traditionally challenging subjects to teach online, adds complexity to the development of many online engineering courses. Demonstrating solutions to problems which involve both graphical and equation-based approaches, for example, typically requires the use of more advanced technology tools. Furthermore, current research continues to link active learning to success in STEM courses. Translating active learning to an online medium poses additional challenges for maintaining quality [5]. On the other hand, some parts of the engineering education process can be improved through the presentation of online courses. For example, constructivist approaches, in which students construct their own knowledge, have been demonstrated to work well online [4]. Furthermore, the practice of self-disciplined online education can be a valuable learning experience for students, as it will likely be more similar to the way they must continue to learn throughout the rest of their life than a traditional classroom setting.

However, the primary challenge, in most cases, involves the question of how to offer laboratory and hands-on experiences. Engineering courses inherently involve a component of practicality, in which the cognitive relationship between the principles presented and the reality of the physical world must be formed and reinforced. For an online engineering course to be of adequate quality, it must be able to provide similar levels of intellectual rigor and engagement, but also, and perhaps most importantly, experiences. In fact, ABET requires that traditional and online courses alike must be accredited against the same criteria, and students should complete the courses having achieved similar capabilities [6]. This matching of rigor and experiences,

even if their formats differ from what has been traditionally done in the engineering classroom, is therefore critical for a successful online engineering course.

Bourne et al. [4] recognize the importance of maintaining quality in online classes, and argue that for online engineering education to be successful, three requirements must be met: the quality must match or exceed the quality of traditional courses, the courses need to be reliably available and accessible, and a broad spectrum of topics needs to be offered. The latter two requirements are more applicable at the program and administrative levels, while the first involves the development of the online engineering course itself and is the focus of this current effort.

Online Engineering Labs

Many student laboratory experiences, even in traditional courses, need more clearly defined learning objectives and assessment methods [7]. Having these items in place will contribute to the ongoing development and discussion of appropriate educational laboratory experiences and lead to the improvement of engineering education overall. To effectively translate lab experiences into a distance-delivered course, the fundamental objectives of any engineering laboratory experience must be understood. Once these fundamental objectives are well understood, then there is a much greater potential for developing new kinds of laboratory exercises that are appropriate for distance learning.

As presented by Feisel and Rosa [7], a set of fundamental objectives of engineering instructional laboratories developed by a colloquy run by the Sloan Foundation in 2002 involve student outcomes regarding:

- Instrumentation
- Theoretical models
- Experimental approaches
- Data analysis
- Design
- Learning from failure
- Creativity
- Use of engineering tools and resources (psychomotor)
- Safety
- Communication
- Teamwork
- Ethics
- Sensory awareness

The above objectives can be divided into three broader categories: Those involving cognition (the first five), those involving psychomotor skills (use of tools and sensory awareness), and those involving behavior and attitudes (the remainder). Feisel and Rosa argue that all three domains are necessary for the development of effective engineers through laboratory experiences [7]. A well-developed online engineering course should work to provide at least a few experiences in these areas to students, some of which can be performed in a manner similar to traditional engineering labs, while others may require more creativity to implement.

Distance education labs historically involved either performing laboratory exercises at another institution or spending a short period on campus for a condensed lab experience [7]. Some more recent innovations for providing lab experiences in online engineering courses involve the use of simulations or remote labs. Simulations have been shown to be comparable to physical labs for explaining and reinforcing concepts, but neither offer opportunity for creativity and curiosity, nor contribute to psychomotor learning [6]. Bourne et al. [4] suggest that it may be difficult, if not impossible to translate these two psychomotor laboratory objectives into an online environment, regardless of the approach. Remote labs, on the other hand, allow students to work with real equipment and instruments, but do not offer the feeling of real presence in a lab and may require a significant investment for the university to set up and maintain the technology [6]. Neither approach would be accurately classified as providing a "hands-on" education.

Yet another alternative approach, one more closely related to the following case-study, provides student with laboratory kits with which they can conduct labs at home. At least one distance education program provided remote students with laboratory kits they could purchase to do some experimental work at home [7]. A second education program shipped "Lab-Kits" for use in Mechanics and Materials labs to be conducted at a distance according to the individual learner's timeline. These Lab-Kits contained materials that would be used in a traditional lab setting such as calipers, micrometers, and scales. Though the course offering was deemed successful in "introducing engineering concepts, developing hands-on skills, and motivating students to become independent learners", it was unsustainable due to budgetary constraints and staffing challenges [8]. Authors Alexander and Smelser conclude that their successes in online delivery of a Mechanics of Materials course with the home Lab-Kits, as demonstrated by such student behaviors as higher risk taking and more in-depth experimentation work with labs, should aid others in developing hands-on online course offerings [8].

Regardless of the approach adopted, a common challenge with distance learning, particularly with regard to lab experiences, is the perceived isolation of students [7]. Tracking student progress and engaging distance learners in a discussion group have been barriers to success in past online Mechanics of Materials courses, despite hands-on components [8]. A successful online course should help to mitigate this effect by encouraging collaboration and communication among students enrolled in the course.

Course Description

The following case study lays out the structure and innovations adopted in an online Mechanics of Materials course. This course was offered by LeTourneau University at an 8-week pace (approximately twice the pace of the traditional course upon which it was based) in the summer of 2016, and was structured as a fully online course. Of the fourteen students enrolled, about half were physically located near to the LeTourneau University campus, and the other half were located at distances too far away to have easy access to campus. Students had weekly homework assignments, including both online and scanned handwritten problems, and a few exams (in a hybrid online and written format) which provided the basis for much of their grade in the course

in a manner nearly identical to how the same course is typically taught in a traditional classroom. This course sought to address some of the challenges facing online engineering courses by:

- controlling course quality with clearly defined outcomes,
- using current technology practices to present lectures and example problems effectively,
- promoting opportunities for student collaboration,
- creating an experiential learning environment,
- aligning with several of the specified laboratory student outcome categories,
- and, ultimately, providing a high-quality course by maintaining the rigor and experiences of a traditional Mechanics of Materials course.

One of the ways to work to improve the quality of online engineering courses is to improve the quality of the learning outcomes attached to those courses. This adjustment will create a more clearly defined metric for determining success in the course, which will in turn allow for a more informed approach in translating traditional practices into the online delivery format. As an example, the outcomes established for the Mechanics of Materials course offered online are shown in Table 1. This list includes outcomes that are achievable and measurable, and assessments aligned with these outcomes were used throughout the course to determine progress in each of these areas. Focusing on addressing outcomes 1, 2, and 3 in particular helped provide the impetus for several of the following course innovations.

Table 1 - Outcomes for Mechanics of Materials Online Course

Upon completion of this course, students will be able to:	
1.	Distinguish numerous real-life applications for mechanics of materials principles.
2.	Differentiate between axial, torsional, and flexural/shear load cases and their applications.
3.	Theorize loading and deformations prior to performing calculations.
4.	Formulate and solve for stresses and strains at different locations in a variety of members and load cases.
5.	Predict structural member deflection and column stability.
6.	Apply mechanics analysis principles in simple design applications.

The majority of content in the course was presented through a series of lecture and example problem videos. These videos were captured using a stylus and tablet, an entry-level studio microphone, and the Doceri interactive whiteboard software. This combination of technology allows for the creation of videos that can very closely resemble the experience of whiteboard-based teaching, but without the losses in sound and video quality that accompany the more common approach of simply recording an instructor teaching at the front of a classroom. Using both pre-made slides and the stylus, this software makes it easy to transition between the teaching mode of explaining concepts and evaluating plots of diagrams and the teaching mode of drawing intermediate diagrams and manipulating equations, much as an instructor in a traditional classroom can go back and forth between a projected screen and a whiteboard. For each topic to be covered, students were typically presented with at least 2-3 videos demonstrating the principles and then 2-3 example problems illustrating their application. Videos were typically kept to a maximum length of 10-12 minutes to help students focus and take natural breaks when needed. When viewing the video materials, students were free to pause, rewind, or even go back to re-watch earlier video lectures and example problems whenever they wished to do so.

To encourage student collaboration, students were placed into “study cohorts” during the first week in the course. These groups of 2-3 students were assembled based on matching student schedules such that each group would likely be working on the course at a similar time each day. The idea behind these groupings was to provide students with an immediate connection to other students enrolled in the same course, regardless of physical location, so they would have a primary option (in addition to the faculty member) available to them if they encountered questions or confusion. To help establish these groups, the first small project was conducted as a group, and it took place in the second week of the course.

Course Innovations

To address the challenges of promoting experiential learning, aligning with laboratory outcomes, and maintaining the rigor and experiences of traditional courses, several course innovations were introduced which were not part of the curriculum in the traditional Mechanics of Materials course. These innovations included:

- Minor Project 1: See Mechanics
- Minor Project 2: Mechanics in Practice
- A mailed physical activity kit for each student

The See Mechanics project required students to work together as a study cohort. As a first step to the project, all students were to take photos of objects or structures that were subjected to loads or stresses and that were located in or near where they were living, wherever that might happen to be at the time. These photos were posted in a private album for each group on a photo annotation and organization website, accompanied by written explanations about what students had decided to photograph and why. As a second step to the project, students were to use the annotation tools on the website to mark up the photos provided by the other student(s) in their group, graphically identifying which members were subjected to the various loading conditions of tension, compression, bending, or shear, and identifying the directions in which the forces or moments were applied. This first minor project allowed students to communicate a little bit about themselves as they worked together, in addition to providing them with some simple but critical experience in relating the concepts discussed in the course to applications in the world around them.

The Mechanics in Practice project was completed by each student individually later in the course. This minor project required students to choose a historical example of an engineering failure that resulted from a negligence or miscalculation related to the principles of Mechanics of Materials. The list of examples from which to choose was provided by the instructor, and included such historical events as the Hyatt Regency Walkway Collapse, the Liberty Ship Hull Failures, the Point Pleasant Bridge Collapse, among others. Students were to research the real-life event of their choice to determine key information such as the purpose of the structure, the events leading up to the failure, the causes of the failure that were related to Mechanics of Materials, and ways the failure could have been avoided. Students were then required to create a one-page mini-poster describing the failure event and the information they had collected and analyzed. This second minor project allowed students to again gain experience in relating concepts discussed in the course to applications in the world around them, but this time they also did so in the context of learning from failures.

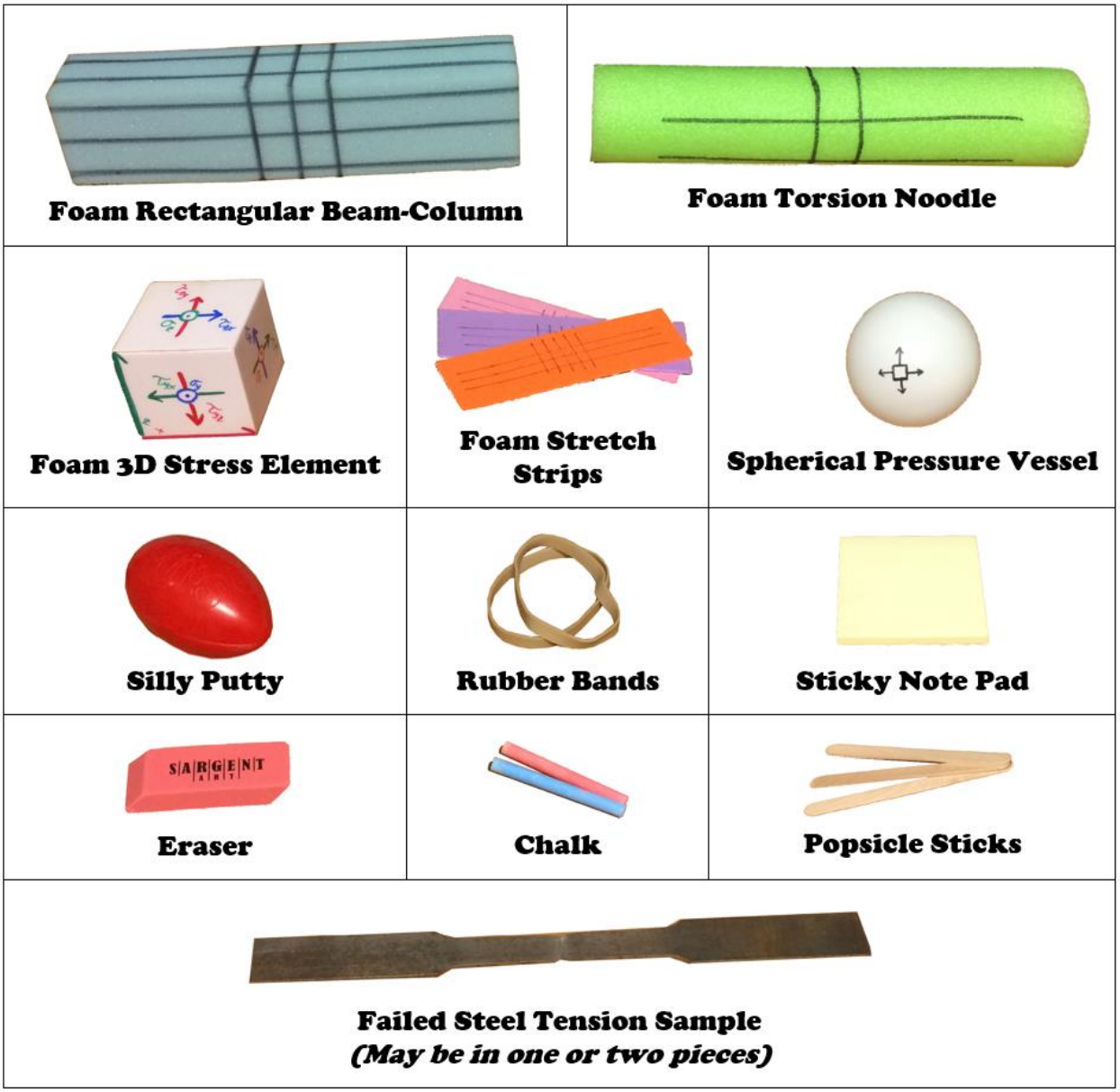

Figure 1 - Physical Activity Kit Materials

The physical activity kits mailed to each student were mostly assembled using affordable components readily available at most supermarkets, with the exceptions in each kit of a foam cube (ordered online) and a failed steel tension sample (obtained from the university's testing lab). A visual list of the materials included in each kit is shown in Figure 1. The top five items shown were each modified by providing identifying markings in order to reinforce various concepts in the course. For example, the foam rectangular beam-column (cut from upholstery foam), once marked with a grid of intersecting lines on each side, became an excellent physical and visual example of how bending a beam creates tensile stresses and strains on one edge and compression stresses and strains on the opposite edge. In a similar way, the foam torsion noodle (cut from a pool noodle toy), with a similar grid and a few longitudinal and transverse slits became an example of torsional and complimentary shear stresses, the foam cube was marked

with identifying normal and shear stress components to help reinforce sign conventions, and foam stretch strips with marked grids were used to illustrate Poisson's ratio. The remainder of the materials shown can be used to illustrate other material properties and concepts related to the principles of Mechanics of Materials.

The completed physical activity kits were mailed to each student such that they received them before the beginning of the course. Throughout the course, students were given written instructions about when and how to use each item in the kits to reinforce the corresponding concepts presented in the lecture and example problem videos. Students were not required to return any of the kit items, but instead were encouraged to keep them as reminders of the material they had learned throughout the course.

The three experiential learning components introduced through the development of this online course included objectives from each of the categories Feisel and Rosa [7] define as necessary for effective engineering laboratory education:

- Cognition category: Theoretical models, addressed by the See Mechanics project and through exercises with the physical activity kit
- Psychomotor category: Sensory awareness, addressed by the See Mechanics project and through exercises with the physical activity kit
- Behavior and Attitudes category: Learn from failure, addressed by the Mechanics in Practice project

While none of these innovations might be individually considered a laboratory experience, they still created opportunities for students to construct their own knowledge about Mechanics of Materials in a manner similar to how a complementary lab might in a traditional course. While there is certainly room for improvement with each of these tools, they still provide an example of the kinds of curricular adjustments that can be made in an online engineering course to provide important experiences similar to those in a traditional engineering course. In addition, different components of these innovations address many of the challenges presented by online laboratory alternatives in that they provide engaging, hands-on experiences and allow for free experimentation and collaboration.

Student Survey Results

In order to assess the efficacy of the format, organization, and innovations introduced in the summer 2016 online Mechanics of Materials course, a student survey was conducted immediately after the conclusion of the course. Most of the questions asked as a part of the survey were specifically addressing individual components of the course and students' perceptions about how those components helped them create connections between the course material and real world applications. This survey was administered online and allowed students to remain anonymous in their responses.

The first series of questions on the survey involved an evaluation of the effectiveness of each of the components in the physical activity kits. One of the questions required the student to self-identify how many of the recommended physical activity kit activities they completed on a scale ranging from none to all. The responses from students who answered "Some," "About half," "Most," or "All" were grouped as "Users" and separated from "Non-users" as shown in Figure 2.

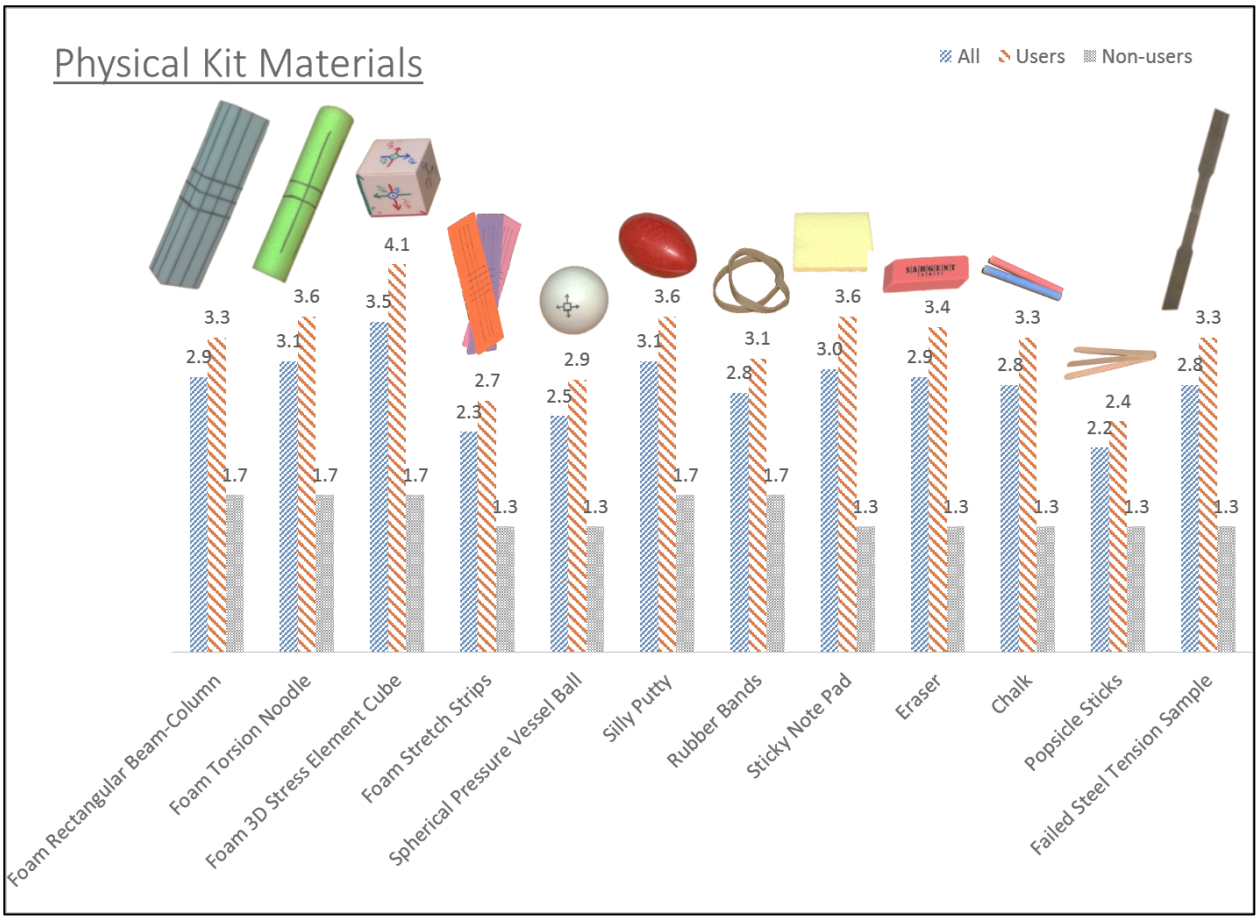

Figure 2 - Survey Ratings on Physical Activity Kit Component Effectiveness

For each component, students were asked to assign a star rating between 1 and 5, with 5 being the best, indicating how well they thought the component helped create connections between the course material and real world applications. On this scale, a score of 3 would be considered a neutral response.

Not surprisingly, the "Non-user" students who opted not to make use of any of the materials perceived their value to be very low. Based on the significantly higher scores of the "User" students, perhaps the "Non-users" would have felt differently if they had made an effort to complete some of the recommended activities. From these results, it seems clear that some items were found to be more useful than others; in particular, the foam beam-column, torsion noodle, stress element, silly putty (used for demonstrating Poisson's ratio and ductility), sticky notepad (used for demonstrating complimentary shear), and eraser (used for demonstrating plastic deformation) were rated among the most useful tools, while the popsicle sticks (longitudinal shear in wood and brittleness), foam strips, and ping pong ball (spherical vessel stress element) were rated as the least useful. Free response comments arose multiple times regarding the physical activity kits indicated that students appreciated the kits and thought they were done well, but also wished that there were videos describing how to make use of the materials instead of simply written instructions. With this in mind, incorporating video explanations in future iterations of the course offers the potential to increase the number of users of the kits, the number

of activities each user completes, and the overall student rating on many of the components included in the kits.

Most of the remaining questions addressed more general student perceptions of the online format and innovations included in the course. For each of these questions, students were required to respond via a typical Likert scale, with responses of “Strongly Disagree,” “Disagree,” “Neutral,” “Agree,” and “Strongly Agree.” These responses were then assigned a numerical value (1: Strongly Disagree – 5: Strongly Agree) in order to obtain numerical averages and standard deviations of the responses. With this rating system, a score of 3 is considered a neutral score.

The first grouping of questions aimed to identify the reasons (if any) students might consider to be responsible for any difficulties students had with the course material. Possible reasons included taking the course in an online format (as opposed to in a traditional classroom), having limited or remote-only access to other students, having limited or remote-only access to the instructor, and taking the course during the summer semester, when employment responsibilities and other distractions might make focusing on the course more difficult. Student responses to these questions are shown in Table 2. A relatively wide range of responses was received for each of these questions, as shown by the high standard deviations, indicating that various students felt that different reasons were responsible for any challenges they perceived with the course. The most highly rated reason for having difficulty in the course was rated to be the online presentation, shortly followed by taking the course during the summer semester. These two responses were expected, given that few of the students had ever experienced taking an online engineering course before and most were employed at internships full-time while enrolled. Despite these two slightly higher ratings, the average response to each potential learning difficulty still came out to be “Neutral” overall.

Table 2 – Survey Summary Regarding Difficulties with the Learning Experience in the Course

Experienced relative difficulty with the learning experience due to:	**Average**	**Standard Deviation**	**Closest Response**
Online Presentation	3.42	0.79	Neutral
Limited access to other students	3.08	1.16	Neutral
Limited access to instructor	2.83	0.83	Neutral
Summer Semester	3.33	1.07	Neutral

The next grouping of questions sought to determine how effective the students perceived the different innovations offered in the class to be at creating connections between the concepts of the course and real-world material behaviors. Students were asked to individually assess each of the minor projects and the physical activity kit first, and then to provide an assessment for the general category of “small projects with practical components.” The numerical results from these questions are shown in Table 3. On average, students appeared to perceive the projects to be a valuable addition for meeting objectives of the course, but felt neutral about the effectiveness of the physical activity kits in their existing form.

Table 3 - Survey Summary Regarding Connections to Real-World Material Behaviors

Perceived contribution to connection between concepts and real-world material behaviors	**Average**	**Standard Deviation**	**Closest Response**
See Mechanics Project (Project 1)	3.92	0.67	Agree
Mechanics in Practice Project (Project 2)	4.17	0.58	Agree
Physical Activity Kit	3.00	0.74	Neutral
-Users Only	*3.22*	*0.67*	*Neutral*
-Non-users Only	*2.33*	*0.58*	*Disagree*
Small projects with practical components	4.00	0.85	Agree

The next grouping of questions asked the students to again generally evaluate effectiveness of the physical activity kits and the "small projects with practical components" at contributing to connections between concepts and real-world material behaviors, but this time to do so in light of the potential they saw in each of those curriculum elements if they were to be improved or adjusted. The results to these questions are shown in Table 4. Most of the students seemed to believe that these innovations offered potential gains in future iterations of the course, with an average response of "Agree" for each question.

Table 4 - Survey Summary Regarding Perceived Potential for Course Components

Perceived potential for adaptation to contribute to connection between concepts and real-world behavior	**Average**	**Standard Deviation**	**Closest Response**
Physical Activity Kit	4.17	0.58	Agree
-Users Only	*4.22*	*0.67*	*Agree*
-Non-users Only	*4.00*	*0.00*	*Agree*
Small projects with practical components	4.25	0.62	Agree

The last grouping of Likert scale questions was even more general in nature, and each were related to the students' general experiences with the course. The results to these questions are shown in Table 5. The first question asked students to assess their confidence that they were able to understand and apply the principles covered in the course. The second question asked students how likely they were to recommend the online Mechanics of Materials course to another student and the third asked how likely they were to take another online engineering course, if the opportunity presented itself. The responses to the first question were quite positive, with an average response of "Agree," while most of the responses to the second and third question were typically either "Neutral" or "Agree."

Table 5 - Survey Summary Regarding General Course Experience

Overall experience with course	**Average**	**Standard Deviation**	**Closest Response**
Able to understand and apply principles	3.92	0.51	Agree
Likely to recommend online course	3.50	0.67	Agree
Likely to take online course	3.25	0.75	Neutral

Table 6 - Survey Free Response Summary

Recurring free response comments on course components that were well done:
Video lectures
Course organization
Physical activity kits
Interesting projects
Recurring free response comments on course components that could be improved:
Heavy work load
Interaction with other students
More example problems
Video demonstrations of use of physical activity kit items

Finally, there were a few free response questions included on the survey that asked students to identify parts of the course that they perceived to be particularly well done or particularly in need of improvement. A paraphrased summary of the four most frequently received responses to each question is shown in Table 6. From these responses, the most important takeaways are that students appreciated the technology used to create the lectures, believed the quality of the course was high, and felt that the physical activity kits and projects were positive additions to the course. In general, they also seem to have struggled to keep up with the work load for the course and felt isolated in their limited interactions with others. The recommendation to include video demonstrations of the physical activity kit items was suggested by several students, and is an excellent and achievable change that will be implemented in the second iteration of the course.

Conclusions and Recommendations

Teaching engineering courses online is, and likely always will be, a challenging endeavor. The practicality and complexity of the subject matter is unique compared to the kinds of courses more frequently taught online in other disciplines. Despite this challenge, however, there is a great potential for online learning in engineering to become a beneficial component for engineering programs if educators are committed to developing high-quality, outcome-focused, and freshly innovative courses.

The Mechanics of Materials course presented as a case study offers an example of what these principles might look like in practice, and the results were largely positive from the subsequent student survey. The use of projects developed to address specific outcomes and the incorporation of a low-cost physical activity kit sent to each student seem to each offer the potential to be significant parts of the process of translating a traditional course to the online medium.

Based on the results of this study, it is recommended that online courses in engineering take advantage of these and similar innovations. Future research with this course would benefit from a comparison of students' understanding of concepts to the same assessment results from a control group of students in a section of the course in which the experiential learning components are absent. A high priority placed on developing student interactions would likely lead to more favorable experiences for students, so future studies should evaluate that aspect of the course, as well. Finally, communicating information and instructions through the use of short

videos may prove to be much more effective than attempting to do so in written form, especially for a course where students are tasked with a heavy work load.

References

1. I. E. Allen, J. Seaman, R. Poulin, and T. T. Straut, *Online Report Card: Tracking Online Education in the United States*, Babson Survey Research Group and Quahog Research Group, LLC, 2016.

2. I. E. Allen and J. Seaman, *Staying the Course: Online Education in the United States, 2008*, Sloan-C, Needham, MA, 2008.

3. United Nations Educational, Scientific and Cultural Organization, *Engineering: Issues, Challenges and Opportunities for Development*, UNESCO, Paris, 2010.

4. J. Bourne, D. Harris, and F. Mayadas, "Online Engineering Education: Learning Anywhere, Anytime," *Journal of Engineering Education*, vol. 94, no. 1, Jan. 2005.

5. S. Freeman, S. L. Eddy, M. McDonough, M. K. Smith, N. Okoroafor, H. Jordt, and M. P. Wenderoth, "Active Learning Increases Student Performance in Science, Engineering, and Mathematics," *Proceedings of the National Academy of Sciences*, vol. 111, no. 23, Jun. 2014.

6. B. Balamuralithara and P. C. Woods, "Virtual Laboratories in Engineering Education: The Simulation Lab and Remote Lab," *Computer Applications in Engineering Education*, vol. 17, no. 1, Mar. 2009.

7. L. D. Feisel and A. J. Rosa, "The Role of the Laboratory in Undergraduate Engineering Education," *Journal of Engineering Education*, vol. 94, no. 1, Jan. 2005.

8. D. G. Alexander and R. E. Smelser, "Delivering an Engineering Laboratory Course Using the Internet, the Post Office, and a Campus Visit," *Journal of Engineering Education*, vol. 92, no. 1, Jan. 2003.