Creating a Hands on Civil Engineering Materials Laboratory Experience at Home

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Creating a Hands on Civil Engineering Materials Laboratory Experience at Home

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Abstract

The academic world turned upside down in March 2020 with the outbreak of the COVID-19 virus. In person classes suddenly transitioned from face-to-face to a virtual environment for the remaining of the spring and into the summer term. One course in particular, Civil Engineering Materials, Codes and Specifications, had been scheduled to be taught in person during the summer. This particular course introduces students to materials used in civil engineering design and construction which includes discussions on material properties. This course contains not only a lecture component but also a very important hands-on-laboratory experience. Recognizing the importance of maintaining a hand on experience, this paper discusses the process in developing a civil engineering materials laboratory kit that students could complete at home. Nine at home laboratory experiments related to testing aggregate properties, making concrete, performing a slump test, reinforced concrete beam construction, testing clay masonry brick, timber testing, analysis of metal specimens and implementation of the International Building Code (IBC) were designed for students to complete at home.

This paper discusses the process of the transition, which includes developing the laboratory experiments, building the laboratory kits and the deliverables required by the students. At the end of the course, students were ask to complete a course assessment where they analyzed the instructor performance as well as the course learning outcomes. This data, combined with student comments that will also be provided, suggest that the course was effective in delivering the content in a meaningful and impactful way. While there is no recommendation to move this class fully online, it was good to know that if necessary this face-to-face laboratory experience could be transitioned to an effective at home experience.

Introduction

Engineering is a very hands on discipline. All engineering programs rely on laboratory experiences to complement and emphasize material taught in lecture. Until 2020, many instructors were able to rely on teaching face-to-face laboratories. During the height of the COVID pandemic, instructors were faced with the challenge of either developing video laboratories for students to watch online and perform data analysis or come up with an approach for an at home laboratory experience. Javaid et. al.\(^1\) presented ways in which laboratories taught as part of electrical and computer engineering courses transitioned the way they were taught due to COVID. Rupak Dua\(^2\) discussed
the use of hands on virtual simulations to effectively teach chemical engineering labs in an online environment. Tyree\(^3\) explains how one instructor at the University of Virginia used virtual labs as part of Introduction to Environmental Engineering course. The instructor had students join a live zoom meeting and had them participate in the lab while the instructor performed an experiment. This paper discusses the development of an at home hands on laboratory kit as part of a civil engineering materials course. Students were required to complete the labs at home and submit a report outlining their findings from each experiment. Student assessment of the course instructor as well as the learning objectives are presented and compared to the previous offering of the course that was in a face-to-face environment.

Description of Course Transition

The academic world turned upside down in March 2020 with the outbreak of the COVID-19 virus. In person classes suddenly transitioned from face-to-face to a virtual environment for the remaining of the spring and into the summer term. CENG 3434: Civil Engineering Materials, Codes and Specifications introduces students to materials used in civil engineering design and construction which includes discussions on material properties. The lectures were converted into short prerecorded videos with each video requiring student to complete a short quiz covering the main concepts from the lesson. There is also a laboratory component to this class that provides a hands on experience. Until summer 2020, this lab had only been taught in person. However, with everything transitioning to a virtual format, it seemed insufficient to simply posting videos of material testing being completed by someone else. This would diminish the student experience. Recognizing the importance of maintaining a hand on experience, this work set out to develop a civil engineering materials laboratory kit that students could complete at home.

The authors came together to develop nine at home laboratory experiments. The labs included: testing aggregates, mixing concrete and making concrete cylinders, constructing a reinforced concrete beam, testing clay masonry brick, determining material properties of steel and timber as well as a lab in interpreting the International Building Code (IBC). A material list was compiled for all labs and 33 lab kits were developed. Figure 1 shows one individual lab kit along with the assembled pieces of the lab kits.

![Figure 1: (a) One assembled lab kit, (b) Assembled pieces of each lab kit](image-url)
For each lab, the instructor developed a video tutorial on how to complete the lab assignment at home. In addition, for a majority of the labs, a second video was developed to help with the data analysis. These video were uploaded to YouTube and posted on the course Canvas site.

**Improving Student Learning**

This particular course has seven primary course learning outcomes that students should be able to successfully perform at the completion of the course. These outcomes will be listed and evaluated in a later section. Six of the seven outcomes have a component that can be tied in with the laboratory experience. It is well known that there are different learning style models used in education today. A model by Linda Silverman and Dr. Richard Felder\(^4\) outlines five primary learning system dimensions. Figure 2 outlines these learning dimensions. This particular approach to teaching is part of the Excellence in Civil Engineering Education (ExCEEd) teaching workshop that is run by the American Society of Civil Engineers (ASCE) each year. Both investigators on this work are ExCEEd teaching fellows. It is often difficult to hit on many of these different learning styles in a class that is fully online and asynchronous. However, providing the class with some hands on experiments to complement the posted videos and reading content allowed more learning styles to be covered. For example, the hands on labs provided a more active learning environment. The labs also gave the sensory learner some physical touch/sensation to understand what is going on.

![Figure 2: Felder and Silverman’s Learning Style Dimensions\(^4,5\)](image)

**Need for Converting to Online**

As engineers, it is important to understand theory and why things behave the way they do. Engineering education is therefore heavily dependent on hands on (active) learning experiences. CENG 3434 is a junior level course with a laboratory component embedded in the class. The easy solution to transitioning this class fully online would be to find videos already developed that cover each of the laboratory experiences for students to watch. Data could then be provided to analyze and generate a report. A more meaningful and impactful approach that will give the students a much better understanding and appreciation for engineering applications is through hand on learning. For example, seeing the impact of the water-cement ratio on concrete workability or how moisture affects the bending strength of wood firsthand by doing experiments as opposed to watching someone else or just reading about it will make a lasting impression.
Evaluation of the Effectiveness

As a deliverable for the laboratory component of this course, each person was required to submit a memo discussing the results they obtained from the collected data. In addition, each student was required to record and upload a video for each of two laboratory assignments showing them performing the lab experiment. The labs were only a part of this course as there was still an asynchronous lecture component with homework assignments, quizzes and exams. Nonetheless, the students were asked to provide an evaluation of both instructor performance as well as their abilities to complete the course learning outcomes. Table 1 is the evaluation of the instructor (Dr. Gangone) for Fall 2019, when the course was previously taught face-to-face, versus Summer 2020 when it was fully online. Both sets of numbers were strong. Table 2 shows the student evaluation of the course learning outcomes compared with Fall 2019. The course director (CD) evaluation is also provided. Both tables present the average score given by students on a 1-5 Likert Scale.

Table 1: Instructor evaluation by students in myUTTyler

<table>
<thead>
<tr>
<th></th>
<th>Fall 2019</th>
<th>Summer 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The instructor clearly defined and explained the course objectives and expectations</td>
<td>4.9</td>
<td>4.8</td>
</tr>
<tr>
<td>2. The instructor was prepared for each instructional activity</td>
<td>4.9</td>
<td>4.9</td>
</tr>
<tr>
<td>3. The instructor communicated effectively</td>
<td>4.9</td>
<td>4.9</td>
</tr>
<tr>
<td>4. The instructor encouraged me to take an active role in my own learning</td>
<td>4.9</td>
<td>4.8</td>
</tr>
<tr>
<td>5. The instructor was available to students either electronically or in person</td>
<td>4.9</td>
<td>4.7</td>
</tr>
<tr>
<td>6. Overall, this instructor was</td>
<td>4.9</td>
<td>4.9</td>
</tr>
<tr>
<td>7. Overall, the course was</td>
<td>4.9</td>
<td>4.6</td>
</tr>
</tbody>
</table>
Table 2: Student and course director assessment of course learning outcomes

<table>
<thead>
<tr>
<th>Table of Course Objectives</th>
<th>Fall 2019</th>
<th>Summer 2020</th>
<th>CD Assess</th>
</tr>
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<tbody>
<tr>
<td>1. I can explain the properties of materials commonly used in civil engineering (other than soils).</td>
<td>4.6</td>
<td>4.9</td>
<td>4.5</td>
</tr>
<tr>
<td>2. I can explain fabrication or method of manufacture of civil engineering materials.</td>
<td>4.5</td>
<td>4.7</td>
<td>4.5</td>
</tr>
<tr>
<td>3. I can apply the specifications used to define the properties of civil engineering materials</td>
<td>4.6</td>
<td>4.8</td>
<td>4.5</td>
</tr>
<tr>
<td>4. I can explain and apply the testing methods commonly used on civil engineering materials (other than soils).</td>
<td>4.6</td>
<td>4.8</td>
<td>4.5</td>
</tr>
<tr>
<td>5. I can explain and apply codes, standards and specifications commonly used in civil engineering.</td>
<td>4.6</td>
<td>4.8</td>
<td>4.5</td>
</tr>
<tr>
<td>6. I can present the results of the lab work in lab reports</td>
<td>4.6</td>
<td>4.8</td>
<td>4.5</td>
</tr>
<tr>
<td>7. I can conduct experiments on civil engineering materials according to the appropriate laboratory procedures.</td>
<td>4.6</td>
<td>4.9</td>
<td>4.5</td>
</tr>
</tbody>
</table>

As mentioned previously, many of the course learning outcomes can be tied to the laboratory experience. The class response for each was very strong with much of this success attributed to this laboratory experience. It should be noted that the course director (CD) evaluation only scored based on 0.5 increments as it is difficult to give a 4.6 versus a 4.7 or 4.8.

The UT Tyler Office of Communications published a story in an online article regarding this particular course and the development of these lab kits. As part of this article there were three students who were interviewed and provided the following comments:

**Student 1:** “It means a lot to me that UT Tyler was dedicated to providing a very educational and challenging course online with hands-on laboratory experience during this pandemic.”

**Student 2:** “My second eldest son has already decided he wants to be an engineer in the future, and this was perfect for him to experience. I want to thank Dr. Gangone for allowing us to do this and also include our families.”
Student 3: "The civil engineering department could have simply pieced together videos and asked us to base our reports on them, but instead, they provided us with the material to do the experiments on our own. What Gangone did for us in the class shows his dedication as a professor."

These comments alone show what great impact this laboratory experience. One aspect of this lab experience that has not been discussed yet was the outreach component. Some of the students in this class are parents or have younger siblings. As part of the lab it was encouraged to get their children or siblings involved in performing the lab experiments with the hopes that it would ignite an interest in entering a STEAM field such as engineering. Student 1 also mentioned, to the instructor, that he involved his son and nephew when working on many of the lab experiments and they are now interested in engineering. One of the most rewarding parts of this particular experiences is that it impacted not just the students in the class but in some cases younger generations.

Summary and Conclusions

This particular experience was a lot of hard work and time consuming to put together. However, it was extremely rewarding. The student feedback along the way and at the end demonstrated the effectiveness that this experience had over just watching a video on how perform a certain lab experiment. The course as a whole was very packed. It was an intense 5 week session. It is extremely important to be available to students when they have questions. Responding to emails or requests for a virtual meeting within 24 hours is important so they do not fall too far behind in the class. Anytime operating an online course like this for the first time requires great organization. The canvas site for this class was built so that each week had a module and the expectations for that week were clearly outlined. In addition, having videos covering the lab procedures as well as how to process data was extremely helpful and provided answers to questions that some students would have had if not provided.

Transitioning to an online environment can sometimes make it difficult to cover everything normally covered in a face-to-face environment. Scaling certain assignments and lessons back to focus primarily on the most critical ones would help. Overall, the students thought the course covered the course learning objectives well and the hands on laboratory experience enhanced their understanding of the material.

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MICHAEL J. MCGINNIS

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