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Applying Student Engagement Techniques to Multidisciplinary Online Engineering Laboratories

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Abstract

As engineering departments continue to expand their online course offerings, they face the challenge of translating onsite best practices into online environments in order to maintain student engagement and enhance student persistence. In this paper we will describe how we implemented and assessed face-to-face classroom techniques related to group discussions and laboratory activities to a new multidisciplinary online course, Engineering Problem Solving Laboratory (EGR 320L) at National University. Specifically, end-of-course evaluations in twelve offerings of EGR 320L were analyzed to see if there was any significant difference between student assessments of online and onsite courses or between engineering and computer science students taking these courses. Before analyzing the student assessment data, the learning activities designed for EGR 320L will be described, which include both synchronous (real-time) and asynchronous elements. The goal was to engage online students as well as onsite students in the multidisciplinary course content that included mechanical engineering, electrical engineering, and thermodynamics. Analysis showed that the multidisciplinary course was very successful since the average teaching assessment scores (on a scale of 1-5, where 1 is poor and 5 is excellent) for both course modes were very high, 4.15/5 for onsite courses and 4.30/5 for online courses.

Introduction

As the number of online courses increases[1], student engagement remains critical to student persistence [2-6] especially in multidisciplinary classes where there are a variety of student majors with a multitude of student learning goals. Student engagement increases when students are able to interact with their professor and their classmates to form learning communities. That sense of community has been studied in terms of both student-instructor interaction and student-student interaction. In a study of 1,400 students across an entire university system, researchers found a significant positive correlation between students' perceived interaction with instructors and fellow students and their satisfaction with their online courses.[7] Additionally, researchers studied student persistence within a single course, and they also found a significant positive relationship between student-instructor interaction and learner satisfaction.[7] Therefore, this paper will focus on how we tried to improve student-instructor and student-student interaction, and thus student engagement, in a newly created, multi-disciplinary course with an associated laboratory at National University.

Scientific Problem Solving (EGR 320) and Scientific Problem Solving Laboratory (EGR 320L) were created in 2011 as multidisciplinary courses that are required for all undergraduate engineering and computer science students, both online and onsite, at National University. EGR 320L uses hands-on computer and engineering tools and the scientific approach to problem solving in a variety of technical areas. Hands-on lab activities in mechanical engineering, electrical engineering, and thermodynamics are conducted by students on both on an individual basis and in a team environment. Critical thinking and communication skills are used to interpret and present results of scientific investigations in the areas of graphical problem solving and statistical problem solving.

Specifically, the student learning outcomes of EGR 320L are the following:

- Demonstrate various scientific problem-solving methodologies.
- Solve scientific problems using innovative computer techniques and strategies
- Apply critical thinking skills to interpret results of scientific investigations
- Participate as a team to solve scientific problems.
- Communicate in oral, written, or graphical form.

The EGR 320L course was taught to both online and onsite undergraduate students in a variety of majors while covering the same course material, but delivering it in different ways. Students taking the onsite course met twice a week with the instructor for 4.5 hours in each class for two months. Students taking the online course meet synchronously (real-time) twice a week with the instructor for 2 hours. The students in both modalities were a mix of engineering and computer science majors; the online students took the course from multiple locations throughout the United States, in addition to military students serving abroad.

Table 1 shows the student enrollment in onsite (OS) and online (OL) courses of EGR 320L, with the number of engineering students (EGR) shown in the second column from the right and the number of computer science students (CS) shown in the far right column. The course assessment data discussed later will be from this group of 156 students, comprised of 89 EGR and 67 CS students from 12 different classes. Some courses were predominantly composed of CS students (course #1, 4, 10, 12) while other courses were predominately composed of EGR students (course #2, 3, 5, 6, 8, 9, 11). One course, #7, had equal numbers of CS and EGR students. Of these 12 courses, half were onsite and half were online courses.

TABLE 1
Enrollment in a multidisciplinary course for engineering and computer science students

Course Offering	Enrollment	Onsite (OS) or Online (OL)	# of EGR students	# of CS students
1	6	OS	0	6
2	4	OL	3	1
3	6	OS	6	0
4	28	OL	4	24
5	21	OS	20	1
6	8	OL	7	1
7	16	OS	8	8
8	14	OL	12	2
9	12	OS	12	0
10	16	OL	3	13
11	9	OS	9	0
12	16	OL	5	11
Total	**156**		**89**	**67**

This paper will investigate student engagement with their instructor and with their peers, as assessed by end-of-course evaluations, in these 12 offerings of EGR 320L to see if there is any variability in student responses in online vs. onsite courses or between engineering vs. computer science students. Before analyzing the student assessment data, the learning activities designed for EGR 320L will be described. The learning activities includes both synchronous (real-time) and asynchronous elements. Specifically, we incorporated large group discussions, small group discussions, and laboratory activities in EGR 320L and tried to engage online students as well as onsite students in the multidisciplinary course content.

Synchronous & Asynchronous Learning Activities

Professors might assume that students gain the most educationally by physically being in the classroom with the instructor and their classmates in order to conduct group discussions and hands-on laboratories. However, some developers of online learning environments suggest that synchronous (real-time) communication may not have advantages over asynchronous communication. One study compared asynchronous discussions on a listserv to face-to-face classroom discussions, focusing on professor and student interactions. They found that asynchronous communication might have some advantages over the traditional classroom, such as students initiating the conversations more often in asynchronous communication.[8] However, other researchers emphasize that synchronous (real-time) discussions had a main advantage of promoting highly interactive discussions, with a disadvantage for the group to digress from the topic to another.[9]

Ultimately both synchronous (real-time) and asynchronous communication each have advantages and disadvantages related to student engagement depending on the student's individual learning preference. For the student who prefers to observe anonymously while learning, a distance learning environment where their body language, focus, and personal activity are masked is preferable. They feel safer and might be more likely to take a risk, such as participating in a group discussion. For the student who likes to look their peers in the eye, read the instructor's nuanced body language, and be able to gesture for meaning, the accountability of being face-to-face is more engaging for that student. Conversely that same student might feel muted in a distance learning environment.

All online classes at National University utilize both synchronous (real-time) activities and asynchronous activities to engage students, in order to reach out to students with different learning preferences. Live synchronous (real-time) chat sessions, asynchronous threaded discussion questions, and other technology tools are used to enhance the online class and engage multidisciplinary students in the course material.

In the synchronous, or real-time, mode the instructor and students meet in a "live" chat session using real-time audio and video and messaging capabilities. The instructor initiates the beginning of the web-based session at the predetermined time, often in the evening. Students log in to the web-based session using our learning management system (LMS), Blackboard. In most Blackboard Collaborate sessions, the student and the instructor have their microphone on so that they can converse in real time. This is supplemented by chat style text communication options and a presentation mode where the instructor can share a document or an application with the entire class. Many students and instructor prefer to have live video feeds as well, but video can have a time lag in the real-time chat sessions. Newer video interface software is beginning to support larger video conferencing capabilities with a greater number of participants (Google Hangout and Zoom are two examples).

In the asynchronous mode, online students interact with course materials individually and at their own time and pace. Students can watch recordings by the instructor or interact with simulations, virtual labs, or other activities that have been linked to the course. The addition of any personal media elements, such as a still portrait of the instructor on the homepage of the course or an embedded video of the instructor introducing themselves, can go a long way toward personalizing the interface and generating a foundational sense of community in an online course.

Discussion boards (called "threaded discussions" in our LMS) are another example of an asynchronous learning activity in online classes at National University. Usually an instructor poses a question on the discussion board and students are encouraged to respond to both the question and to each other's responses. One common problem with threaded discussion questions is that students tend to simply regurgitate textbook equations or the textbook author's examples. By including examples of everyday items in the threaded discussion, students can be engaged by relating the theory in the textbook to familiar items in their daily lives. Examples of threaded discussion questions in the mechanical engineering part of EGR 320L are included below:[10]

- You are walking down the road, listening to your iPod with your earbuds. You trip and your iPod tumbles out of your pocket but is caught by the cable connecting it to your earbuds. How would you calculate the stress in the cable? What assumptions would you have to make? What equations and data would you use?
- For the iPod tripping scenario above, how would you calculate the elongation in the cable? What assumptions would you have to make? What equations and data would you use?
- You were lucky when you tripped - the cable was strong enough to support the weight of the iPod when it flew out of your pocket. What's the maximum weight that can be supported by the cable attached to the earbuds? How could you test this experimentally?

EGR 320L was designed with a variety of synchronous (real-time) and asynchronous learning activities in order to increase student engagement with the multidisciplinary course material. Group discussions and laboratory activities are easily done in a traditional onsite class, but are much more difficult to conduct in online classes. Yet the goal of National University is to ensure that students get the same high quality course whether the student takes the class onsite or online. Therefore, the first example will describe how the instructor conducted online small group discussions in EGR 320L. The second example will describe how hands-on laboratory activities are incorporated into the online class.

Online Small Group Discussions

Small group discussions are a key tool for promoting student engagement, but scheduling several synchronous small-group discussions in an online environment can be a logistical challenge. With Blackboard Collaborate, an instructor can easily gather students into one large chat room and then divide the large group into concurrent sub-groups utilizing separate chat rooms. Within these small group chat rooms, each student has access to audio, video, text chat, application sharing, and a whiteboard to document notes during the session. The instructor can jump in and out of each small group, encouraging and guiding students as necessary. Once complete, instructors can aggregate the whiteboard notes in the main online chat room and reconvene the whole class for group reports. Thus students in online classes can be involved in small group discussions while in a synchronous chat session with their instructor and classmates, very similar to small group discussions in an onsite class.

We applied this online, synchronous, small group discussion technique to the thermodynamics module of EGR 320L. Before the students conduct the hands-on thermodynamics lab at home, the instructor distributed a lab report to the online class with instructions to analyze its strengths and weaknesses. During the synchronous (real-time) chat session, the instructor then divided the online students into small groups and placed them separate chat rooms where their task was to grade the lab report using the rubrics that the instructor usually uses. Using the LMS technology described previously,[10] the instructor could then visit the individual chat rooms (shown as Room 1, Room 2, etc. in Figure 1). The instructor could see who was using the microphone when it was highlighted in yellow (the microphone icon in the 4th column in Figure 1) or who was typing in the chat window (the balloon icon in the 6th column in Figure 1). For the sake of privacy, student names were removed from the participant window and replaced with generic labels in Figure 1.

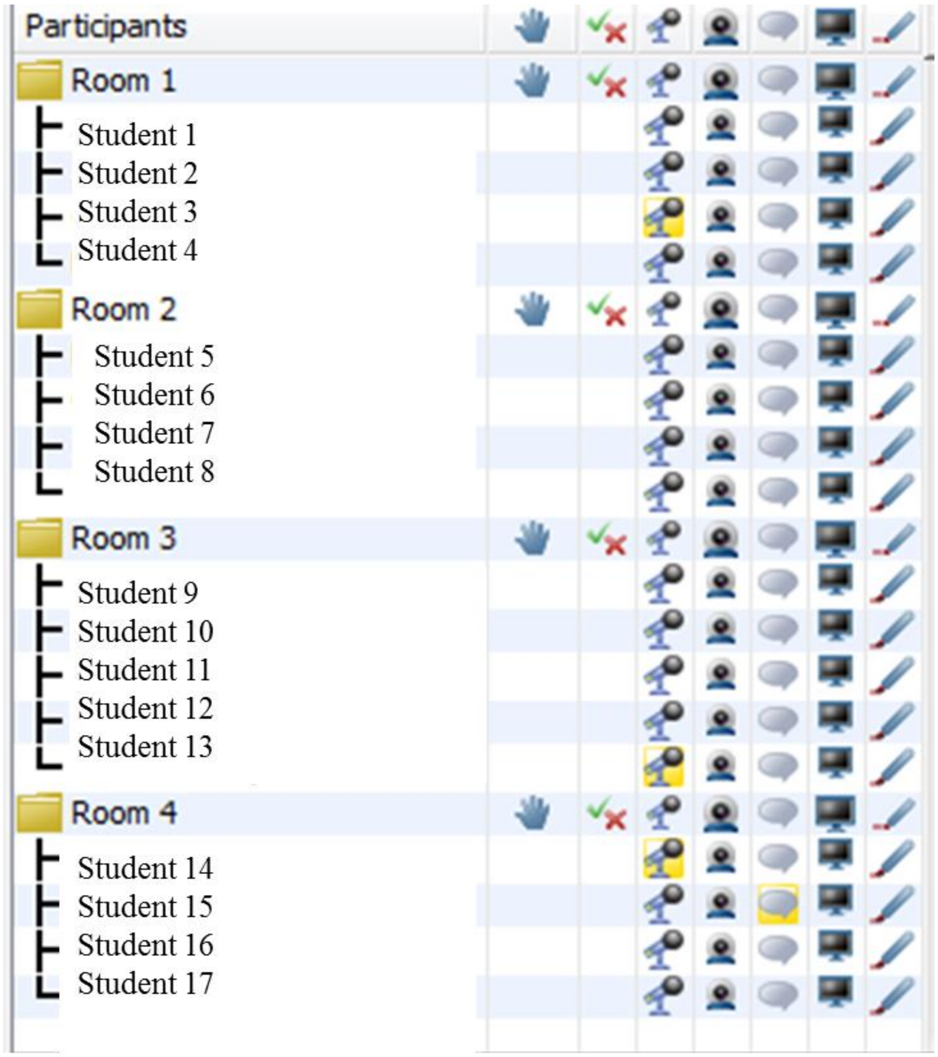

FIGURE 1

LMS tools used to facilitate online small group discussion in EGR 320L

The students in the small group could type their comments onto the PowerPoint slide that contained the instructor's grading rubric, as well as write their score of each element as it was discussed. At the end of the activity, the whiteboard notes from each small chat room were brought into the main chat room for student presentation. A spokesperson from each small group could then describe their group results to the whole class.

Online Laboratory Activities

In addition to the small group discussion technique discussed above that can be used in all online classes, EGR 320L included additional elements to engage students through a variety of educational activities such as demonstrations, simulations, a virtual (video) lab, two hands-on labs, and a student team project. The virtual (video) lab for mechanical problem solving and the hands-on lab for electrical problem solving will be described in this section.

Specifically, the first module in EGR 320L applies graphical problem solving techniques to solve a mechanical engineering problem. The mechanical engineering problem was first posed in a threaded discussion question described earlier, “You are walking down the road, listening to your iPod with your earbuds. You trip and your iPod tumbles out of your pocket but is caught by the cable connecting it to your earbuds. What's the maximum weight that can be supported by the cable attached to the earbuds? —What assumptions would you have to make? —What equations and data would you use?”

To put the stress/strain theory and equations into practice, a laboratory activity was developed to try to experimentally answer the question posed above – what is the maximum weight that can be supported by the cable attached to the earbuds. But instead of simply adding weights to a cable to see when it broke, we put a sample of cable into a tensile testing machine to systematically pull the cable with ever increasing force until the cable broke. Onsite students could run the Admet tensile testing equipment themselves when the EGR 320L class was taught in the laboratory classroom. But for online students, another option was necessary, so we created a virtual (video) lab where tensile testing measurements were video recorded for an earbud cable being pulled until it broke. The online students watched the 5-7 minute video recordings for each sample, recorded the force and elongation data, and then graphed the calculated stress and strain data on the earbud cable. A selection of plain metal and plastic materials were also tested in the tensile testing machine so that students had data for plain metal and plastic to compare to the composite earbud cable. A screenshot from one of the virtual (video) labs, showing the sample being held on the left and the data output (force in Newtons and elongation in mm) is shown in Figure 2.

FIGURE 2
Virtual (video) lab for mechanical engineering in EGR 320L

The second module within EGR 320L focused on statistical analysis of data, where the data was from resistance and voltage measurements of simple DC circuits. There were five experimental steps in this lab on electrical problem solving, followed by statistical analysis of all student data. The statistical analysis focused on accuracy, precision, and sources of error by examining the calculated mean and standard deviation of all the resistance and voltage data, and by examining the percent error in the measured value compared to the known value of the resistor. The five experimental steps were:

1. Measure the resistance of individual resistors.
2. Measure the resistance of resistors in series.
3. Measure the resistance of resistors in parallel.
4. Build a series DC circuit and measure voltage across each resistor.
5. Build a parallel DC circuit and measure voltage across each resistor.

Again, onsite students could build the circuits on the breadboard and take multimeter measurements themselves when the EGR 320L class was taught in the laboratory classroom. But for online students, another option was necessary. Instead of a virtual (video) lab, which was used for the mechanical engineering problem solving module described previously, we shipped hands-on laboratory equipment directly to each student to create remote labs and adapt hands-on laboratory learning to online courses. The students received myDAQ equipment from National Instruments. According to the National Instruments website, "NI myDAQ is a low-cost data acquisition (DAQ) device that gives students the ability to measure and analyze live signals anywhere, anytime. NI myDAQ is compact and portable so students can extend hands-on learning outside of the lab environment using industry-standard tools and methods. NI myDAQ addresses student needs for the following: multiple instruments on one low-cost DAQ platform; portable, USB-powered, and built to last; and instant relevance, programmability, and project-readiness."[11]

Student Assessment of Teaching

At the end of each course at National University, a survey is given to each student about their perception of teaching and learning. The students are asked to record their responses on a scale of 1-5, where 1 is poor and 5 is excellent. There are 12 questions on the student perception of teaching in online classes:

1. Instructor was well organized.
2. The instructor encouraged student interaction.
3. Instructor responded promptly to emails and other questions.
4. Method of assigning grades was clear.
5. The instructor gave clear explanations.

6. Instructor was receptive to questions.
7. The instructor was an active participant in this class.
8. Instructor encouraged students to think independently.
9. Instructor was available for assistance.
10. Instructor provided timely feedback on my work.
11. I received useful comments on my work.
12. The instructor was an effective teacher.

The survey given to onsite students is the same, with slight variations in questions 2, 3, and 7:

1. Instructor was well organized.
2. Class time was used effectively.
3. Content areas described in the course outline were covered.
4. Method of assigning grades was clear.
5. The instructor gave clear explanations.
6. Instructor was receptive to questions.
7. Instructor stimulated critical thinking.
8. Instructor encouraged students to think independently.
9. Instructor was available for assistance.
10. Instructor provided timely feedback on my work.
11. I received useful comments on my work.
12. The instructor was an effective teacher.

End-of-course evaluations of EGR 320L were tabulated to see if there is any variability in student responses in online vs. onsite courses or between engineering vs. computer science students. Table 2 shows the mean of all the student responses in the survey of student perception of teaching in EGR 320L. There were two course offerings, #3 and #11, with no available course evaluation data.

In the courses that were predominantly comprised of CS students (course #1, 4, 10, 12), the teaching assessment scores ranged from a minimum of 3.59 to a maximum of 4.69, with an average of 4.21 and standard deviation of 0.51. In the courses that were predominately comprised of EGR students (course #2, 5, 6, 8, 9), the teaching assessment scores ranged from a minimum of 3.33 to a maximum of 4.84, with an average of 4.31 and standard deviation of 0.70. One course, #7, had equal numbers of CS and EGR students and had a mean teaching assessment score of 4.0. This data suggests that EGR 320L was equally engaging to both engineering and computer science students, since the range of teaching assessment scores were very similar in both groups. Also, the new multidisciplinary course was very successful, with overall teaching assessment scores that averaged 4.2/5 from computer science students and 4.3/5 from engineering students.

Finally, assessment data was compared for onsite and online EGR 320L classes. The teaching assessment scores from onsite classes ranged from a minimum of 3.79 to a maximum of 4.77, with an average of 4.15 and standard deviation of 0.43. The teaching assessment scores from online classes ranged from a minimum of 3.33 to a maximum of 4.84, with an average of 4.3 and standard deviation of 0.66. Again, the multidisciplinary course was very successful since the average teaching assessment scores for both onsite and online were very high, 4.15/5 and 4.3/5 respectively.

Tab1e 2

Student assessment of teaching in EGR 320L classes

Course Offering	Teaching assessment (scale from 1-5)	Onsite (OS) or Online (OL)	# of EGR students	# of CS students
1	4.02	OS	0	6
2	4.84	OL	3	1
3	N/A	OS	6	0
4	4.69	OL	4	24
5	4.77	OS	20	1
6	3.33	OL	7	1
7	4	OS	8	8
8	4.8	OL	12	2
9	3.79	OS	12	0
10	3.59	OL	3	13
11	N/A	OS	9	0
12	4.55	OL	5	11

Qualitative student self-assessment of small group, online, synchronous discussions applied to a thermodynamics lab report in EGR 320L was overwhelmingly positive. Both engineering and computer science students reported enhanced analytical and communication skills throughout the activity. The biggest hurdle that needed to be overcome by both students and the instructor was the fear of trying something new. In the classes included in this study, a majority of students reported that they had taken at least five online courses previously; however, only a few of the

156 students reported that this small group chat function of the LMS had been used in other classes. Another practical hurdle was that, since students had never done this before, they did not have a headset with a microphone or the audio quality of the built-in microphone in their computers was quite poor. Also slow internet speeds or increased bandwidth due to dozens of students talking at once can cause audio lag at times, which frustrated students and instructors momentarily while communications were disrupted.

Other hurdles encountered in the implementation of small group discussion in synchronous chat session were the same hurdles reported in traditional onsite classes: some students immediately started to dominate the discussion in their own group, or participation was sluggish at first with only a few text messages appearing in the chat window, rather than students taking the microphone to discuss the assignment with their classmates. Continuous group monitoring and quick instructor response was the key to enhancing the student participation in the chat sessions, just as instructor intervention is needed in onsite classes to keep students on task, prevent vocal students from dominating the discussion, and encourage universal student participation in the activity.

Qualitative student self-assessment of laboratory activities was overall positive, with many suggestions for future iterations. Below are some examples of the anonymous student feedback received on the end of course evaluations:

- “The myDAQ distribution and experiment is definitely an aspect of the course I would continue. This hands-on learning experience provided useful insight and learning.”
- “The myDAQ was awesome.”
- “The use of MyDAQ in home was awesome. I wasn't expecting to be able to perform experiments at home and I found it very satisfactory to actually be able to do experiments myself. Thank you.”

In addition to the course evaluations, many students emailed feedback to the instructor. As with most engineering and computer science courses, the number of male students was higher than the number of female students. But positive feedback was received by email from many female students in EGR 320L, who had initially expressed great reservations about doing hands-on laboratory activities by themselves at home. At the end of the class, one female engineering student wrote, “The program itself was pretty explanatory, like any useful computer program it took a little poking around and testing but isn’t that what an experiment is all about? A few you tube videos on how a breadboard works and I was good to go with setting up and testing each of the resistors and then the different series and parallel configurations. Much to my surprise I was actually spot on with my other classmates on the readings, and I can’t even begin to tell you the elation I felt!” Similarly, a female computer science student wrote, “The LabVIEW software interface was the best part of the lab. Nice GUI interface, user friendly and easy to manipulate ...

Definitely a challenge I will never forget." This student feedback was very encouraging, given all the hurdles to student persistence that female students face in engineering education.[12]

The use of the hands-on myDAQ lab equipment sometimes went beyond the electrical engineering module. Some students created team project ideas for the final assignment using myDAQ. For example, another computer science student wrote, "MyDAQ usage was a very interesting way of learning … as I got used to it, it became very easy to use and was actually very helpful … I used myDAQ for the term project as well." One team project used myDAQ and several sensors (temperature, pressure) to create a prototype sensor system and software feedback that would activate an alarm if a child was left in a car seat in a warm automobile.

One suggestion for improvement came from a student who takes online classes with a Mac instead of a Windows computer, "The week 2 lab experiment was more than the adventure than it needed to be. If you're going to use web-based equipment, you need to ensure the providers of the drivers/programs actually have Mac and Windows-based install software available. As a Mac user, I was forced to go way out of the 'ordinary' plug-&-play that my Windows-using classmates to gain the same result enabling me to use the test equipment."

Finally, instructors gave positive feedback for these hands-on labs for online classes. One professor wrote, "This is the first time using myDAQ in online labs - a big challenge but I'm glad we tried it."

Conclusions

In summary, online classes at National University use both synchronous (real-time) chat sessions and asynchronous threaded discussions to engage students and to replicate the onsite student experience in small group discussions and hands-on laboratory activities. Each instructional mode has several advantages for increasing student engagement and persistence in online courses. Live synchronous chat sessions, asynchronous threaded discussion questions, and other technology tools were used to enhance the online class and engage multidisciplinary students in the course material of EGR 320L. Real time, synchronous chat sessions used technology tools in our LMS to facilitate small group discussions in online classes. National Instruments equipment, myDAQ, was shipped to online students to facilitate hands-on laboratories in electrical engineering. Virtual (video) labs were used to engage students in mechanical engineering. Student feedback was overall positive on the variety of engagement techniques used in this multidisciplinary course. Assessment data from over 150 online and onsite students, both in computer science and engineering programs, showed that teaching evaluation scores were very similar in range and mean, regardless of class mode or student program. In fact, the highest mean score for the student perception of teaching was 4.3/5 in online courses, showing that multidisciplinary, laboratory-based engineering courses can be successfully taught online with engagement between professors and students.

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