2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #32716

Lessons Learned: Making the "New Reality" More Real: Adjusting a Hands-on Curriculum for Remote Learning

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Lessons Learned - Making the “New Reality” More Real: Adjusting a Hands-On Curriculum for Remote Learning

In 2017, the Mechanical Engineering Department at Seattle University was awarded a National Science Foundation Revolutionizing Engineering Departments (RED) grant. The project focuses on creating a department culture that fosters engineering identities by immersing students in a culture of doing engineering with engineers [1] - [7]. As part of this culture change, the department implemented several major curricular changes beginning Fall 2019 [1] - [4]. These changes were designed to give students hands-on engineering experiences and engage them with practicing engineers. The department introduced a new required integrated design sequence for the first, second, and third-year students [3], [4]. The new design sequence complements the existing year-long, industry-sponsored senior design experience. The circuits and instrumentation courses were replaced with a lab-focused, two-course sequence combining circuits and instrumentation curriculum [7]. Senior design was retooled to better reflect the experiences of working engineers [3], [4]. In addition, the department implemented changes in existing courses by adding industry driven design projects [3], [4]. All these changes relied heavily on group projects, hands-on labs, and in-person meetings with industry representatives. In the spring of 2020, a pandemic forced the program to offer all its courses remotely and challenged the department to rethink how it could continue its strong hands-on, industry-focused program while fostering a sense of belonging in students. While changes occurred throughout the curriculum to support remote learning, these changes were exemplified in three course sequences: integrated design, circuits and instrumentation, and the year-long capstone design. The remainder of this paper describes these three course sequences, their adaptation to remote instruction, the lessons learned, and how these lessons may affect future course offerings.

Integrated Design Courses

The integrated design sequence consists of three coordinated courses taken by all department first, second, and third-year students simultaneously in the spring term each year. Each week includes two hours of classroom instruction to each class-year separately, and two hours of design project time to teams of 5-7 students integrated from all three class-years. Projects are guided by a faculty member and volunteers from local engineering firms. The projects allow students to practice the engineering design skills they are learning in the classroom, while also creating opportunities for organic interactions between diverse groups of engineers with different levels of experience.

The classroom and project work in these courses was intended to be in-person, and hands-on. To accommodate the transition to remote learning the design project was modified. Individual teams identified a pandemic-driven problem, and then proposed a conceptual solution to that problem. This shift was effective in keeping students motivated but lost the hands-on elements. Students enjoy the build and fabrication phase of design because it provides a sense of accomplishment and allows students to test and troubleshoot their product. Additionally, a traditional design-build problem allows first and second-year students to be more involved in the fabrication phase. With the shift to conceptual solutions, the second and third-year students tended to drive the conceptual solutions since they have more upper-level coursework. One successful outcome was that third-year students took on leadership roles and practiced delegating work based on skill level. This experience taught us that the integrated design experience can be a success without fabrication.

The move to remote learning meant that student interactions shifted from traditional (and comfortable) in-person meetings to virtual platforms. We positioned this challenge as an opportunity, as many firms use communication apps to conduct regular business. We proceeded as though the design teams were composed of engineers living in different parts of the country and moved the entire course to the Microsoft (MS) Teams platform. Each team monitored the group channels and had their own channel to work on. Students appreciated the context of this shift. They worked in the online environment well but building community without in-person interactions was difficult. Although our data (to be presented in later publications) indicate that students felt more a part of their teams and the department by quarter's end, we assume that in-person experiences would have magnified these effects. Nonetheless, using MS Teams for coordinating project work added a value, including the ability for some team members to attend meetings when they might not otherwise be available. We will continue with MS Teams after the pandemic, as an addition to, not as a replacement for, in-person interactions. Similarly, we originally had intended to bring volunteer consultants to campus to help the students with their project work. With the shift to remote instruction, consultants could participate via MS Teams from their home or office. Because engagement was easier, we had a much higher participation rate, and consultants stayed engaged with our students for longer than anticipated. This was the biggest advantage of, and lesson learned from this experience. We will continue to use virtual tools to maximize industry engagement in the integrated design experience moving forward.

Circuits and Instrumentation Courses

The circuits and instrumentation curriculum is a two-course sequence covering electrical engineering (EE) concepts, instrumentation, microcontrollers, and fundamentals of IoT (Internet of Things). The courses consist of two one-hour lectures and two two-hour labs each week where students learn EE concepts and apply them to a related instrumentation project. Details of this course sequence including example projects and assessments can be seen in Ref. [7]. The first course, except for the last week, was in person. The second course was entirely remote. The transition to remote instruction presented several challenges. First, students relied on lab equipment, such as power supplies, soldering irons, and the electronics stockroom to complete their projects. Second, lab projects were configured as team projects to capture the teamwork and collaboration frequent in the workplace. Third, labs were designed with open-ended components with the assumption that the instructors would be present to help students when they were unable to make progress. Several changes were made to address these challenges.

The course content was flipped by moving lecture material to online videos and supplemental reading material. Prior to each class meeting, students were assigned problems related to the day's video lecture. Instead of meeting with the entire class for one hour, the instructor met with a "pod" of 10-12 students for 20 minutes to work on the assigned problems. This provided students more personal help and attention. Since the course focuses on hands-on experience, retaining that focus was important during remote learning. Prior to the start of the remote second course, the labs were reworked so that they could be completed at home. Students were sent a USB device that included a two-channel scope, multimeter, signal generator and low current power supply, as well as a list of components they needed to purchase (as a prefilled shopping cart with components for a breadboard, power supply, electronics, and sensors). The cost for this purchase was less than the lab fees students normally pay for in-person labs. In addition, students were required to have a computer for software development and internet access over WiFi. Labs were held synchronously using Zoom. Students worked in teams of two and collaborated through a code sharing extension on the development platform. Students also worked together to create and submit their lab reports using MS OneNote. The instructors used code sharing and OneNote to help students during lab sessions. The IoT capabilities of the microcontrollers made it possible for students and the instructors to monitor another student's microcontroller [8] remotely and was useful for debugging. Overall, the labs were successful as they retained hands-on experiences with little compromise to the originally planned lab content. However, there were several challenges. First, some students did not have reliable WiFi. This affected Zoom meetings, their ability to collaborate and debug remotely, and the IoT services to their devices. Second, helping students debug circuits was challenging in a remote setting--students often had to send close-up pictures to instructors via emails or MS Teams chat when they encountered difficulties. The instructors had to fully understand the problem to be able to guide the student to provide relevant details and do the actual debugging. Although more effortful, this approach led to deeper student engagement as students had to take a greater role in problem-solving.

Senior Design Courses

The department has a year-long senior design sequence. Students work in teams of 4-6 on an industry-sponsored project, often resulting in a functioning prototype. Each team has a faculty advisor and works closely with a liaison engineer from the sponsoring company. During the 2019/2020 academic year, senior design projects started in person and transitioned to remote learning in March. At that time, all teams submitted a COVID-19 transition plan that explained how they would complete their project and whether any changes in scope were required. These plans were approved by the university and industry sponsors. The transition to remote learning posed several challenges and opportunities. Because the health regulations did not allow students to meet in person, building physical prototypes was challenging. Some teams were able to complete the prototypes they had begun earlier by dividing physical builds among team members with personal access to fabrication tools. Other teams completed detailed CAD drawings and simulations without physical parts. These “paper” projects were perceived by some students as less successful. The department emphasized that the success of an engineering project is frequently unrelated to a physical build and successful projects are those that achieve the goals set forward in the project scope. At the end of the academic year, all students were required to create a short video describing their project. The university then hosted a conference-style online event where student teams from all engineering departments presented their work. This event was successful and had over twice as many participants as when held in person. The online format allowed people outside of Seattle to join the event and interact with our students.

Lessons Learned

In shifting to remote instruction, the department learned several things that will inform the curriculum and its delivery both during the pandemic and into the future. 1) Online communication tools and collaborative software are essential for community building. They allow more student-to-student, student-to-faculty, student-to-industry interactions; they reduce the time commitment and increase the participation of industry volunteers and result in better community engagement. Without the necessity created by the pandemic, the department would have underestimated the value of these tools. 2) Hands-on experiences in remote learning can be created with sufficient effort and planning. For many courses, modern collaboration and simulation tools make it possible to provide meaningful hands-on experiences without the need for expensive lab equipment. The department will be reevaluating is lab courses in the light of its successful experience with remote labs in an effort to provide individual hands-on experiences and reduce the overall costs of labs. 3) Not being able to generate a physical prototype in every instances more accurately captures the breadth of engineering practice. While most faculty understood this, the experience with remote learning highlighted the need to emphasize this to students throughout their program. Having a better understanding of engineering work can help to motivate students when working on design-only type problems and better prepare them for their futures. 4) Remote instruction forced the department to find new ways to assess students’ experiences. Documenting students’ experiences, whatever the format, is informative and can help a department address the challenges of creating a more inclusive and engaging program. Details of the department’s findings will be reported in future publications. 5) Community building is essential. It is easy to minimize community building in favor of content delivery, but remote instruction emphasized the value of community. Community provides a support structure that helps with student success and retention. 6) Curricular innovation can be driven in part by university support. In response to the pandemic the university adjusted the quarter to give faculty an extra week to prepare for the first quarter that was fully remote. They also provided summer short courses on how to better design and deliver online courses. 7) In the same way that we prompt students to challenge their assumptions, departments need to challenge theirs. It should not take a pandemic for creative, innovative teaching to occur.

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