Board 110: Work-in-Progress: Engaging Students in Remote Delivery of an Electronic Printing Laboratory Course

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In the United States, there are growing concerns of a science and engineering talent shortage. Recruiting the young generation to STEM and inspiring them to pursue related careers is crucial, but it is equally important to retain current STEM students and help them complete their bachelor's degrees successfully. In [1], two academic factors are identified that impact student retention in engineering programs, namely: (1) difficulty of the curriculum and (2) poor teaching and advising. Engineering is known to be a difficult discipline. For the Accreditation Board for Engineering and Technology (ABET) accredited engineering programs, students are expected to achieve several learning outcomes including an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics. However, students may form inaccurate perceptions of the level of difficulty of complex engineering problems when they cannot see a clear link between a given class and its relevance in their future career [2]. It feels harder when there is a lack of appreciation for why these courses are included in the curriculum. If an engineering course helps students clearly see the point of learning, students are more likely to persist in completing the course.

Laboratories are an integral component of the ABET-accredited engineering curricula and courses. Laboratories provide students with the opportunity to learn by doing. This hands-on experience helps students to develop a deeper understanding of engineering course content. Laboratories often require students to work in groups to complete projects, which fosters collaboration and teamwork skills. They help to prepare students for their future careers by exposing them to the safety training, tools, equipment, and processes that they will encounter in their future professional engineering practice.

Since 2000, there have been reported research on exploring virtual laboratory in engineering and science. A virtual engineering laboratory is presented in [3] for hybrid electric vehicle starter/alternator experimentation. A virtual laboratory environment is developed in [4] for an electronic circuits course. Using interactive TV and the internet, Gurocak [5] created a new approach for distance delivery of a Manufacturing Automation laboratory course. Compared to traditional, in-person laboratories, virtual laboratories in chemical engineering can greatly promote students' critical thinking and higher order cognition, as well as facilitate a broader experience for students [6]. Kolloffel and Jong [7] reported similar findings in their study on electrical circuits, students in the virtual laboratory condition achieved better conceptual understanding and developed better procedural skills.

Though virtual laboratory is a viable option for engineering education, most engineering laboratory courses are offered in person, simply because of the nature of intensive hands-on laboratory components, cost of equipment, and inability of students to manipulate equipment remotely. In addition, there is also valid concern that students in some virtual laboratories may not receive sufficient sensory input and physical interactions with equipment. While around 320 engineering schools in the U.S. have received accreditation from ABET, only a handful of those offer engineering programs that are completely online at the graduate and/or undergraduate level [8]. Research on virtual laboratory has picked up the pace when emergencies like COVID-19 occur and call for remote delivery of instruction. Virtual laboratory studies have been designed in chemistry and chemical engineering [9-12], civil engineering [13], mechanical engineering [14-15], and computer programming and networking [16-17]. Major tools and platforms for virtual laboratories include instructional videos for laboratory protocol and instruction [9],

interactive simulations [11, 13, 16], at-home laboratory experiments [10], and remote access to equipment [3, 14].

Electronic Printing Laboratory (EPL) was established by the first author in 2015. The EPL is equipped with two Optomec's Aerosol Jet (AJ) 200 Systems (see Figure 1) and their supporting equipment (such as ink and substrate preparation systems, circuit curing system, water purification system, testing instrument and so on). The EPL course was designed based on the uses of the laboratory equipment. It has been offered in every spring semester since 2016 as a regular laboratory course for both undergraduate and graduate students in Electrical Engineering (EE) program. The EPL course requires students to utilize electronic printers to print circuit traces, surface mount electronic components on a printed board (or a substrate) to form functional electronic circuit, and test the circuit for correct behavior (i.e., the verification of electronic theories). Upon the completion of the laboratory course, students will learn various stages of electronics prototyping: circuit layout design (via Auto CAD software), electronic printing, surface mounting, and system assembling and testing.

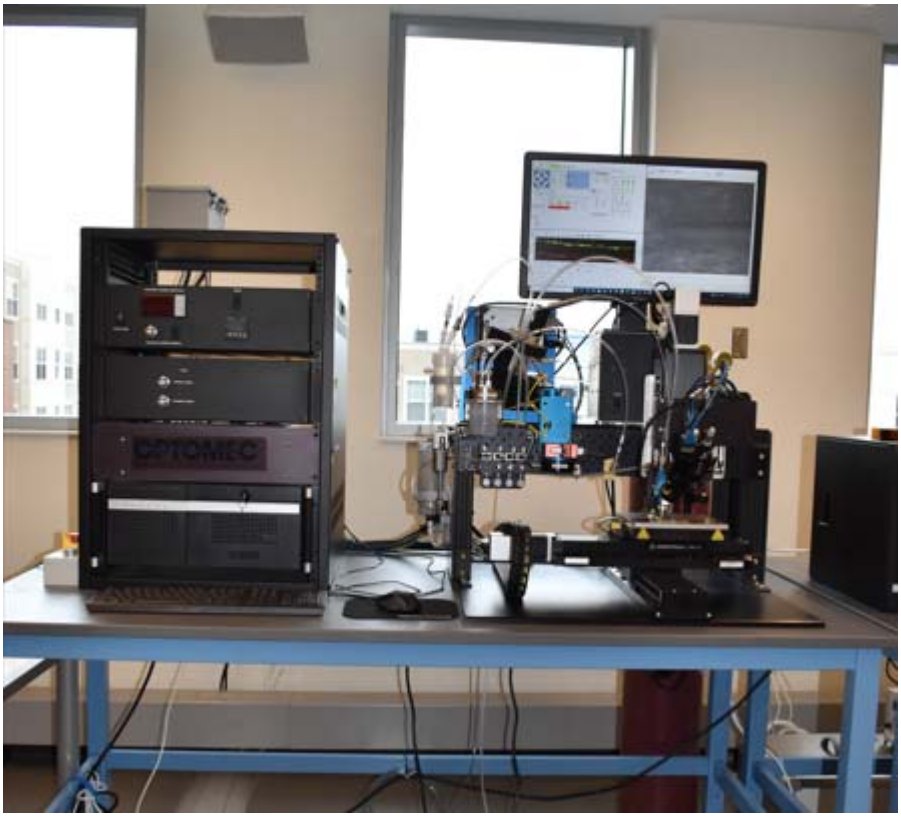

Figure 1. Aerosol Jet (AJ) 200 Systems in EPL

This EPL course aims at meeting industrial needs and preparing students for their future career in electronic manufacturing. Since the circuit printing must be performed in the laboratory (there is no remote access), and the cleaning of the printer parts must be done by hands, this EPL is primarily offered as in-person, even during COVID-19 pandemic time. There has been a need to explore strategies for remote delivery of this laboratory course not only for emergency situations,

but also for accommodating non-traditional students who desire a flexibility of in-person and virtual options.

Objectives

This project intends to address the engineering student retention issue by developing an individualized, interdisciplinary, and experiential Electronic Printing Laboratory course for Electrical Engineering undergraduate students. Believing that laboratory courses form an essential component in any engineering curriculum, this project will redesign the existing experiments in the Electronic Printing course in a way that maximizes individual contribution while encouraging teamwork and reinforces the math and science concepts. This project will also create a set of new experiments for at-home exploration of advanced electronics and enables students to see the curriculum as exciting and relevant to life outside of the classroom. Additionally, the project will explore strategies to engage students in remote delivery of the Electronic Printing course.

Laboratory remote activities development

A close examination of the EPL course content revealed that while the circuit printing and post processing of circuit printing must be performed in the laboratory, circuit layout design can be done at home with AutoCAD software. Moreover, the testing and measurement of printed electronic circuits can be completed remotely via Analog Discovery 2 (AD2), a portable and multi-functional testing tool. We have used the Adobe Captivate software program to develop tutorial videos and interactive simulations for laboratory protocol, Aerosal Jet Printing software operation, and AutoCAD design for circuit layout.

We also developed new experiments for at-home exploration of advanced electronics for the EPL course to ensure that every student has an opportunity to complete each stage of electronics prototyping, has a clear idea of the division of work, and understand the synergetic effect of teamwork. The following is one example to illustrate how we have adapted the laboratory experiments for remote activities. In the EPL course, students are required to design the circuit layout in the laboratory computers with the aid of AutoCAD software. To implement the hybrid or remote delivery, students are instructed to download AutoCAD software (free educational version) to their personal computers and design the circuit layout at home. Laboratory instructors hold zoom meetings with the students during the class time to monitor and guide the design process remotely. After the completion of circuit printing and curing in the laboratory, students and laboratory instructors use AD2 to test their circuits. AD2 is an affordable, portable, multi-function, full-featured tool that students can use at home to measure, visualize, generate, record, and control both analog and digital signals. It can be configured to work as traditional instruments, such as an oscilloscope, spectrum analyzer, network analyzer, power supply, signal generator, and digital multimeter. Figure. 2 shows an experimental setup for circuit testing. From this figure, we can see that a printed circuit is connected to AD2 for performance evaluation and measurement. The measured signal is then sent to the computer for display. To test an amplifier circuit, students can use the AD2 to power and excite the amplifier circuit with included DC power supply and wave generator. There is also a mini oscilloscope in AD2 device. Using the function of oscilloscope, students will be able to observe the input and output signals on a

computer screen through an interface software between AD2 and printed circuit board. Instructors can supervise and instruct students to complete the laboratory activity remotely. Our EE program has 25 sets of AD2 for instructional laboratory usage. We plan to apply the AD2 devices to electronic printing laboratory remote activities.

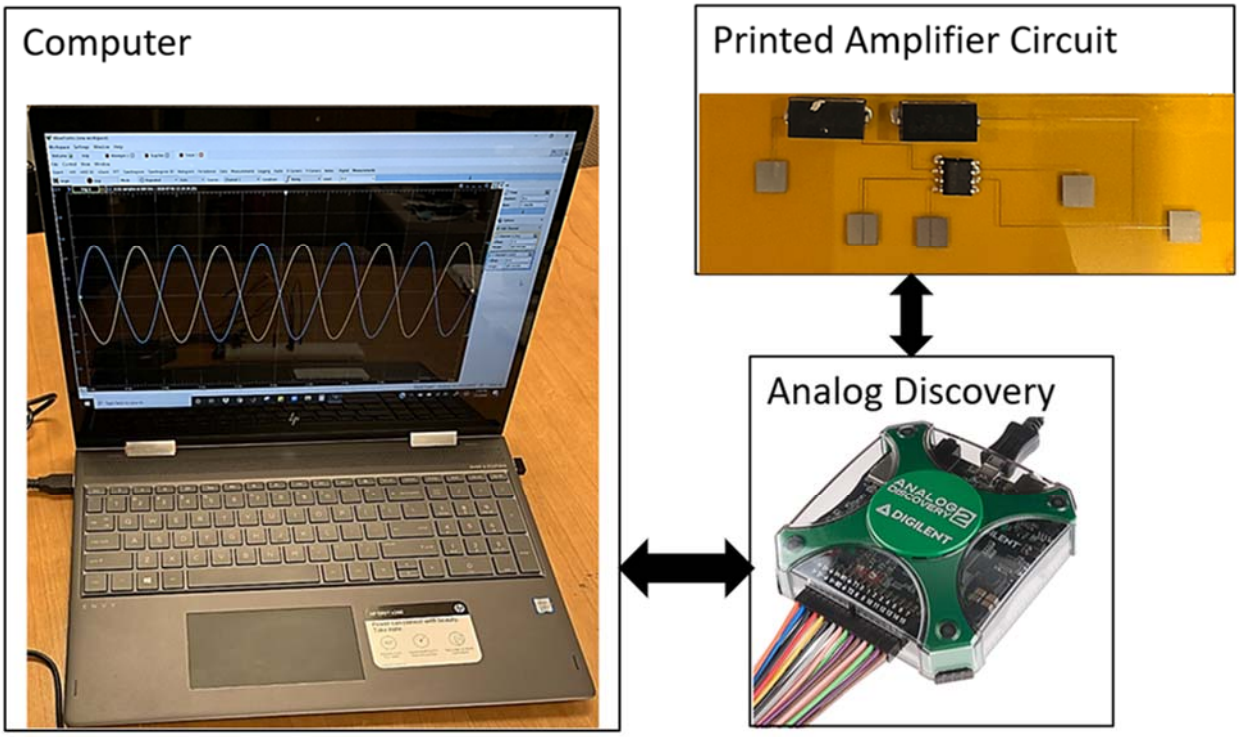

Figure 2. Experimental Setup for Remote Activity (Circuit Testing)

Research design

We obtained the Institutional Review Board's (IRB) approval for this research project. Currently, we are in the process of completing this study. We are recruiting participants from students who completed or currently enrolled in the EPL course. We plan to have 10 students who completed the EPL in the traditional in-person condition and 10 student who will complete the online components of the EPL. Willing participants will complete a semi-structured interview via zoom as well as give the researchers the permission to analyze their course project reports. The semi-structured interview will guide respondents to reflect on their learning experience in EPL (for example, what aspects of this class contributed most to your learning). It will seek their input on remote delivery of EPL. Finally, it will gather their self-assessment of their skill development in circuit design, AutoCAD circuit layout design, 2D electronic printing, and system assembling and testing.

Students' course project reports will be rated. Ratings will be used to determine the effectiveness of the proposed online laboratory content. Interview recordings will be transcribed and analyzed to corroborate quantitative findings from students' course project reports, and to assist us in understanding what strategies best engage students in remote delivery of the Electronic Printing Laboratory course, which might be applicable to other EE laboratory courses as well.

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