Course-Based Undergraduate Research in First-Year Engineering

Extended Abstract

This presentation describes an adaptable model for implementing a course-based undergraduate research experience (CURE) in an introductory engineering design and computing course. Students work toward course learning outcomes focused on computer programming, engineering design processes, and effective teamwork in the context of multi-term research and development efforts to design, build, and test low-cost microcontroller devices. Project customers include professors implementing CUREs in science lab courses, other needs at the college, and community partners. Students choose from a menu of projects each term, with a typical course offering involving four to five different projects running simultaneously. Each team identifies a focused design and development scope of work within the larger context of the project they are interested in. They give weekly progress reports and gather input from their customers. The work culminates in a prototype and final report to document their work for student teams who will carry it forward in future terms.

CUREs are differentiated from other course-based engineering design projects (e.g. design competitions) by the following characteristics [1]:

- Course outcomes are developed in context of new research questions/directions each term. Research efforts progress and shift focus term-to-term.
- Students engage in authentic practices representative of research in the field.
- Students must troubleshoot, problem-solve, and repeat aspects of their work.
- Students have opportunities to share project results with interested stakeholders outside the classroom.

We teach this course on an 11-week quarter system, starting with a three week “crash course” on computer programming and microcontrollers featuring lab tutorials and a series of mini-design challenges synthesizing increasingly sophisticated combinations of sensors, indicators, and actuators. Brief lectures and peer instruction on key programming concepts complement the tutorials. Homework includes interactive reading assignments and programming assignments. Instruction in weeks four and five shifts focus to the engineering design process in the context of a highly scaffolded project to design, build, and program a model traffic signal. This project gives students a context to practice new programming skills and develop the team they will continue with for the larger research project that follows. Weeks five through seven introduce some new programming content as students engage with the background research, problem specification, and ideation phases of their project. Starting week eight, class time is allocated for students to work with their teams to implement and troubleshoot their projects with technical support from the instructor and lab technician.

Table 1 summarizes the fall 2023 projects. The presentation will include an example project prompt, student work artifacts, and a discussion of the multi-term implementation model.

Table 1. Fall 2023 research and development project titles.

Project Title	Social Context	Customer
Remote Collection of Ticks for Biology Research	Local public health	Biology Professor
Stream Flow Remote Monitoring for Geology Research	Local impact of climate change	Geology Professor
Spray Chamber Development for Chemistry Research in Photovoltaics	Improving solar power technologies	Chemistry Professor
Low-Cost Negative Pressure Wound Therapy	Improving Health Outcomes in Developing Nations	Local Medical Doctor

We assessed the impact of the experience using a nationally normed survey for CUREs in STEM [2]. We chose this survey because there is benchmark data available to compare how student responses to the CURE compares to results from other types of undergraduate research experiences (UREs). We collected survey data over five course offerings: spring 2018, fall 2018, spring 2019, fall 2019, and fall 2023. We found statistically significant pre-post gains on two-thirds of the survey items relating to students' understanding of the research process and confidence in their STEM abilities. Figure 1 shows the eight items (out of 24 total) with the largest gains. Reported p-values are from a paired two-tailed t-test.

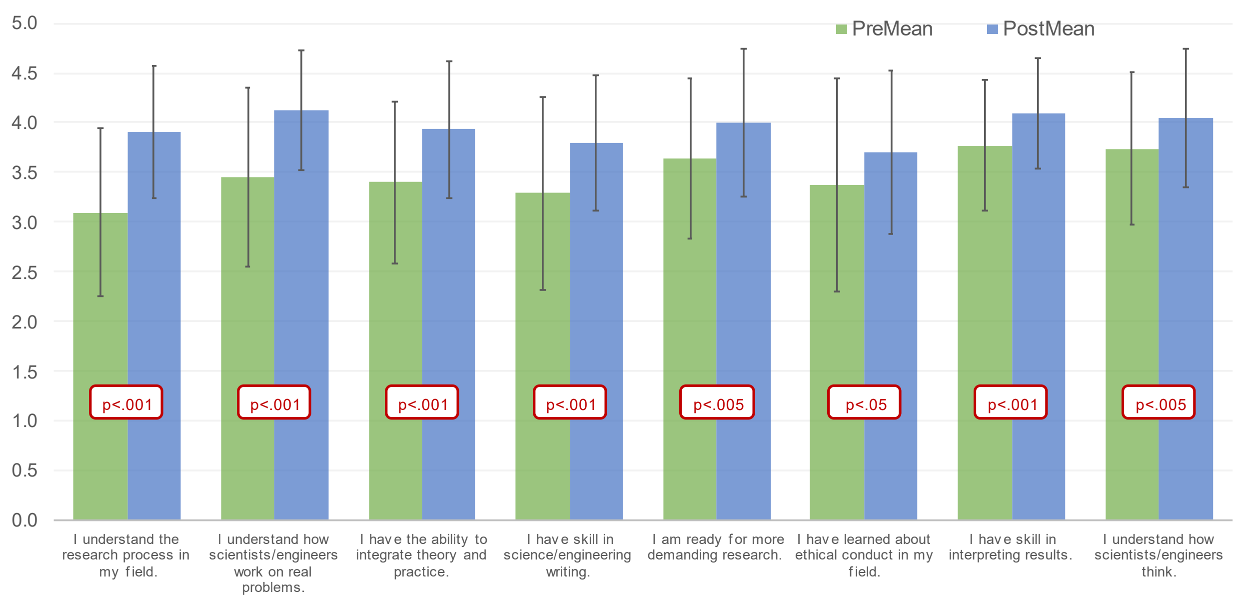

Figure 3. Pre/post survey results for the eight survey items with the largest gains.

These pre-post gains are comparable to results reported by others who used the same survey to assess the impact of a summer research experience for community college students [3]. These findings indicate that the benefits of student participation in this CURE model are comparable to the benefits of summer research programs.

References

[1] "CUREnet: Course-based Undergraduate Research Experiences," Science Education Research Center at Carlton College, [Online]. Available: https://serc.carleton.edu/curenet/whatis.html. [Accessed February 2024].

[2] D. Lopatto, "Undergraduate Research Experience Surveys," [Online]. Available: https://sure.sites.grinnell.edu/cure-survey/. [Accessed February 2024].

[3] A. G. Enriquez, N. P. Langhoff, W. Pong, H. Mahmoodi, X. Zhang, C. Chen, K. S. Teh and Z. Jiang, "Developing a Summer Research Internship Program for Underrepresented Community College Engineering Students," in *2017 ASEE Annual Conference and Exposition*, Columbus, OH, 2017.