Board 231: Contextualizing Engineering Science Courses by Teaching History and Judgement

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Dr. Rachel Vitali is an Assistant Professor in the Mechanical Engineering Department at the University of Iowa. Prior to her appointment, she was a NASA-funded TRISH postdoctoral fellow in the Industrial & Operations Engineering Department at the University of Michigan, where she also received her B.S.E. in 2015, M.S.E in 2017, and Ph.D. in 2019 from the Mechanical Engineering Department. As director of the Human Instrumentation and Robotics (HIR) lab, she leads multiple lines of research in engineering dynamics with applications to wearable technology for analysis of human motion in a variety of contexts ranging from warfighters to astronauts. In addition to her engineering work, she also has an interest in engineering education research, which most recently has focused on incorporating authentic engineering educational experiences through engineering history education and open-ended modeling problems designed to initiate the productive beginnings of engineering judgement and engineering identity.

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Introduction

Engineering programs have long struggled with balancing curricula that are rigorous enough to prepare graduates to be capable practitioners and educational experiences that are engaging enough to retain undergraduate students. Over the past 60 years, data collected from a variety of institutions across the United States capture an alarming trend – only about half of students who start in an engineering program will actually graduate with an engineering degree [1]. Several studies found that the first-year engineering curricula, which traditionally consist of physics, chemistry, and mathematics courses, are ineffective in motivating students to persist in a program [2]. Many students who leave after their first or second year explain that they came to dislike engineering or lost interest in the profession altogether [3]. Together, these findings suggest a mismatch between what incoming students think engineering is and what message they receive during their first two years of a program.

To address retention issues in the first year of an engineering program, many institutions now employ a first-year design experience intended to expose students early on to the true nature of engineering [4]. However, the engineering science courses that occupy a significant proportion of the middle two years of a program still most often utilize traditional lecture-based pedagogy and simplified close-ended textbook problems, which do not typically allow students to make the connection between these classes and the engineering design process or the engineering profession. These types of closed-ended problems also do not provide students with the opportunity to engage in the kind of decision-making that leads to developing sound engineering judgement [5-6]. Recent work developing and studying the effects of open-ended modeling problems define an opportunity to provide students with challenging problems that simultaneously reinforce their understanding of course material and expose them to the realities of engineering practice [5-6].

This NSF-funded work proposes introducing two different pedagogies into a Mechanical Engineering program at the University of Iowa. The first pedagogy is designed to provide a more holistic contextualization of engineering practice by introducing students to the history of the profession. The second instructional technique is intended to provide students with context for how engineering science concepts are implemented in authentic engineering practice and how engineering judgement is essential in that implementation. This work will aim to understand how historical and/or technical contextualization of what it means to practice engineering can influence the intentions of students, particularly those identifying as underrepresented minorities and women, to persist in a discipline that historically struggles to retain them. With this understanding, changes can be made to undergraduate engineering education to better retain students.

Methods

In the Mechanical Engineering program at the University of Iowa, second-year students are required to attend a program seminar intended to educate students about the program and profession for which they are currently being trained. Previously, this seminar has been limited to a third of the semester that focused specifically on aspects of the program itself (e.g., required curriculum, technical electives, and student design groups). The seminar was redesigned in Fall 2023 to also include context on engineering as a profession, including how the profession got started, how different subdisciplines of engineering developed, and the importance of various forms of communication in the profession.

During their second year, Mechanical Engineering students also typically enroll in an introductory dynamics course alongside students from other departments including civil engineering and biomedical

engineering. A project has been added to one section of the dynamics course offered in the Spring 2024 semester that consists of a series of open-ended modeling problems (OEMPs) that the students work on during the courses' associated discussion sections [7]. While students necessarily exercise and develop their engineering judgement in design and lab courses, OEMPs provide opportunities to hone this judgement by directly applying engineering science content to make and justify assumptions. Here, students work in groups to develop mathematical models that describe a real-world scenario [5-6]. In doing so, students must employ their engineering judgement to make assumptions and simplifications, and to assess the reasonableness of their model and final answer.

At the end of each semester, students enrolled in the associated courses are invited to participate in a survey, which consists of Likert-type items regarding their intention to persist and open-ended questions regarding their perceptions of the nature of engineering practice. The items are averaged to produce an overall intention to persist score ranging from 1 (already intending to change their major) to 5 (very confident that they will earn an engineering degree). The open-ended question responses will be systematically coded to uncover common themes in students' descriptions regarding what they believe the nature of engineering is.

Results and Discussion

In Fall 2023, 116 students were enrolled in the required program seminar. The response rate for the survey distributed at the end of the semester was 72%. Figure 1 illustrates the overall persistence of students enrolled in the second-year seminar at the end of the Fall semester. The mean and median of the data are 4.5 and 4.6, respectively, which reflects the very positive skew present in Fig. 1. While there are some students who, over the course of the semester, decided to switch out of the Mechanical Engineering major, approximately 92% of the enrolled students persisted in mechanical engineering into the Spring 2024 semester.

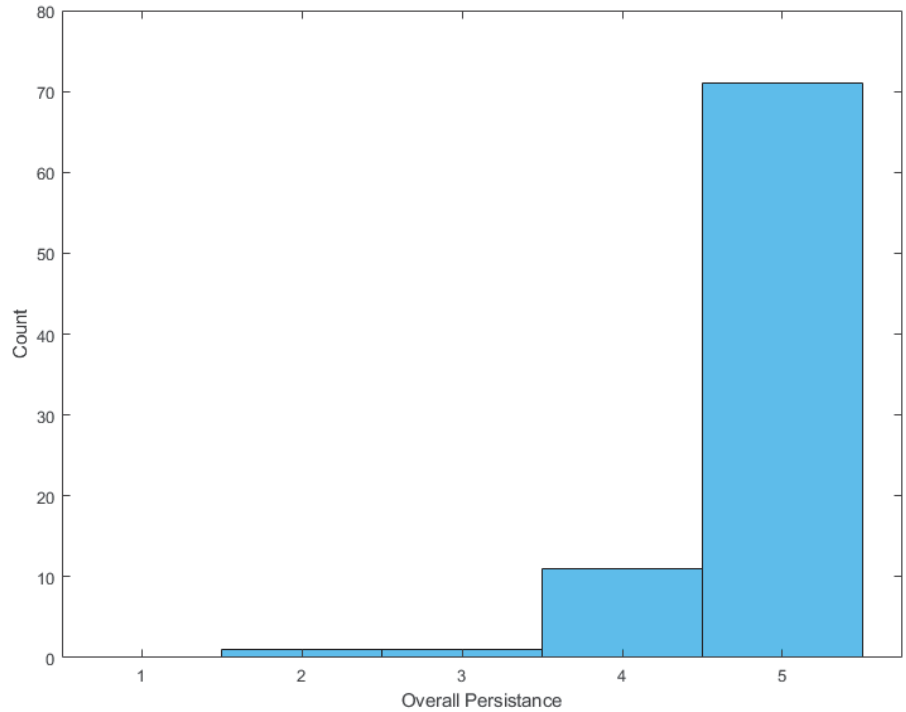

Figure 1: Overall persistence for the participants who completed the survey in Fall 2023.

Conclusion

Future work includes additional survey data collections as well as conducting semi-structured interviews with students who engaged in one, both, or none of the instructional techniques and how that influences their perceptions. This work will advance the field of engineering education research by studying how students' perceptions of engineering practice develop as they progress through a program, and how historically and technically contextualized educational activities can shape that progress and/or reframe their beliefs about their education and training. The semi-structured interviews in particular will reveal how students' perceptions of engineering practice change longitudinally and the degree to which the aforementioned educational activities influence that trajectory. In addition, the larger group of students who are invited to participate in surveys will enable us to draw inferences from a broader sample about intention to persist as well as baseline levels of familiarity with engineering in general. This work will contribute new knowledge about students' understanding of what it means to practice engineering and how that understanding changes with exposure to different types of contextualization. It will also contribute new knowledge about how undergraduate students associate engineering science and judgement with engineering practice, particularly with respect to how these facets of engineering practice are directly in service to design.

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