Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025
Paper ID #47664

PFE:RIEF - Contextualizing Engineering Science Courses by Teaching History and Judgement

Martell Cartiaire Bell, The University of Iowa

I'm am a second year Ph.D student in Mechanical Engineering at the University of Iowa with a dual focus in engineering education and automation/artificial intelligence in manufacturing.

Dr. Aaron W. Johnson, University of Michigan

Aaron W. Johnson is an Assistant Professor in the Aerospace Engineering Department and a Core Faculty member of the Engineering Education Research Program at the University of Michigan. His design-based research focuses on how to re-contextualize engineering science engineering courses to better reflect and prepare students for the reality of ill-defined, sociotechnical engineering practice. Current projects include studying and designing classroom interventions around macroethical issues in aerospace engineering and the productive beginnings of engineering judgment as students create and use mathematical models. Aaron holds a B.S. in Aerospace Engineering from Michigan and a Ph.D. in Aeronautics and Astronautics from the Massachusetts Institute of Technology. Prior to re-joining Michigan, he was an instructor in Aerospace Engineering Sciences at the University of Colorado Boulder.

Prof. Rachel Vitali, The University of Iowa

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.

PFE:RIEF - Contextualizing Engineering Science Courses by Teaching History and Judgement

Introduction

Engineering programs strive to offer curricula that are both rigorous enough to produce competent, professional practitioners and engaging enough to retain their enrolled students. Over the past 60 years, data from various U.S. institutions reveal a concerning trend that only roughly half of the students who begin an engineering program actually graduate with an engineering degree four to six years later [1]. Research indicates that the traditional first-year courses in physics, chemistry, and mathematics often fail to inspire students to continue in the program, especially as they limit opportunities for students to develop their engineering identity [2]. Despite efforts to incorporate engineering experiences into the first year of a program, many students who leave after their first or second year report that they grew to dislike engineering or lost interest in the field entirely as a result of their experiences in these math and science courses [3]. These findings suggest a disconnect between incoming students' expectations of engineering and the reality presented during their initial years in the program.

As part of a wide effort to combat retention issues associated with the first half of an engineering program, many institutions now incorporate a first-year design course that necessarily exposes students to the true nature of engineering, usually in way that incorporates active learning [4]. While these first-year experiences have been shown to be beneficial in retaining more students [5], these courses alone are not a complete solution. For example, the engineering science courses comprising the bulk of the middle two years of a program tend to persist in utilizing traditional teaching methods like lecturing and simplified close-ended textbook problems. These pedagogies afford students very few opportunities to relate the skills and analyses taught in these classes to the engineering design process or the engineering profession. The closed-ended problems usually make assumptions for students that simplify the problem, which does not provide them 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 PFE:RIEF-funded work introduces 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 paper builds upon previous work [6] 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.

Methods

In the Mechanical Engineering program at a large Midwest research-intensive university, second-year students are required to attend a program seminar intended to educate students about the program and the profession. This seminar has historically lasted a third of the semester, and educated students about different facets of the program such as the required curriculum, technical electives, and student design groups. The seminar was redesigned in Fall 2023 by the first author to include context on engineering as a profession as well as details on how the profession formally started, how subdisciplines of engineering emerged from Civil Engineering, and the importance of communication in the profession [7].

During their second year, Mechanical Engineering students are required to take an engineering dynamics course. Students from other departments like Civil Engineering and Biomedical Engineering enroll in this dynamics course as part of their major as well. Pursuant with this research, a project has been incorporated into a section of the dynamics course offered in the Spring 2024 and 2025 semesters. For this project, students engage with open-ended modeling problems (OEMPs) during the courses' associated discussion (recitation) sections [8] [9]. While design and lab courses provide students with opportunities to exercise and develop their engineering judgement, OEMPs can be designed to hone this judgement by using engineering science content to make and justify assumptions. For the OEMP integrated into the dynamics course, students work in groups to develop mathematical models that describe a real-world scenario [8] [9], which requires that they employ 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 five 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 responses were coded to uncover common themes in students' descriptions for what they believe the nature of engineering is.

Results and Discussion

Table 1 below shows the enrollment for the semesters in which the pedagogical interventions were implemented. The overall response rate across courses for the survey was 67%.

Table 1: Description of courses and student enrollment information.

Semester	Course	Enrollment
Fall 2023	Program Seminar	116
Spring 2024	Dynamics	55
Fall 2024	Program Seminar	117

Figure 1 illustrates the persistence of students enrolled at the end of the semesters and courses listed in Table 1. The mean and median of the data are 4.6 and 4.8, respectively, which reflects the very positive skew present in Figure 1.

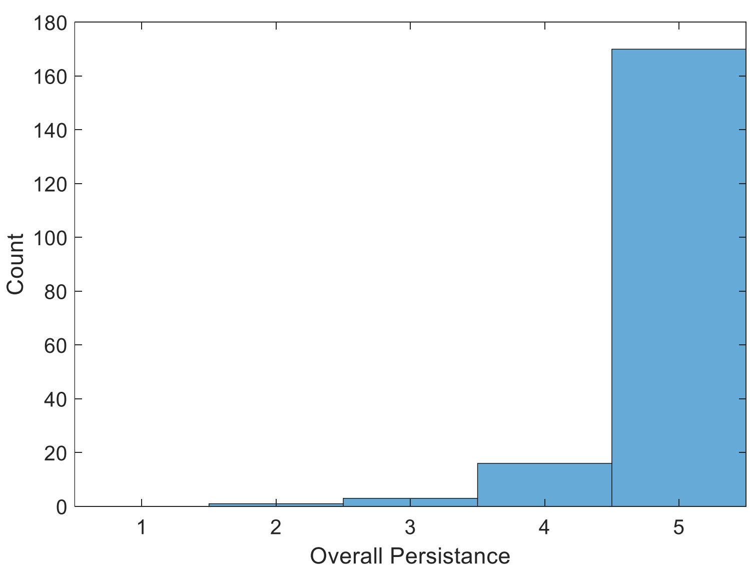

Figure 1: Overall persistence for the participants who completed the survey.

The responses to the open-ended survey question regarding the students' perceptions of engineering practice were coded systematically to uncover common themes. Students perceive the following ten themes as being part of engineering practice: 1) considers ethics, 2) considers safety, 3) considers efficiency, 4) considers complexity, 5) utilizes knowledge, 6) collaborates with others, 7) improve or make designs, 8) solves problems, 9) improve life, and 10) personal career aspirations. About half of students described engineers as people who solve problems, around a third reported that engineers should consider safety and improve live, and approximately a quarter responded that engineers should utilize knowledge and improve or make new designs.

Between Fall 2023 and Fall 2024, changes were made to the mechanical engineering program seminar in the hopes that students would report more well-rounded perceptions of what engineering practice is. The results were mixed. More students in Fall 2024 reported that engineers should consider ethics, safety and efficiency as well as utilizes knowledge and collaborates with others. Interestingly, fewer students stated that engineers improve life or improve or make designs than the students who were enrolled in the program seminar in Fall 2023. Approximately the same proportion of students reported that engineers should consider complexity and problem solve as well as describing their own personal career aspirations between both semesters.

Conclusion

Future work includes additional survey data collections as well as conducting and analyzing 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 contribute to the research by investigating how students' perceptions of engineering practice develop as they progress through a program, and how contextualizing different educational activities can influence their beliefs and understanding. The semi-structured interviews will provide rich data describing how students' perceptions of engineering practice change over time.

Additionally, inviting a larger group of students to participate in surveys enable this work to make inferences from a broader sample regarding their intention to persist and their baseline familiarity with engineering. This research will provide new insights into students' understanding of engineering practice and how this understanding evolves with exposure to various types of contextualization. It will also shed light on how undergraduate students link engineering science and judgment with engineering practice, especially in terms of how these aspects directly support design.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Award No. 2306052.

References

[1] B. Geisinger and D. R. Raman, "Why They Leave: Understanding Student Attrition from," *Interntational Journal of Engineering Education,* pp. 914-925, 2013.

[2] N. Honken and P. Ralston, "Freshman Engineering Retention: A Holistic Look," *Journal of STEM Education,* vol. 14, no. 2, pp. 29-37, 2013.

[3] E. Seymour and N. M. Hewitt, Talking About Leaving: Why Undergraduates Leave the Sciences, Boulder, CO: Westview Press, 1997.

[4] L. Prendergast and E. Etkina, "Review of a First-Year Engineering Design Course," in *ASEE Annual Conference*, Indianapolis, IN, 2014.

[5] M. Hoit and M. Ohland, "The impact of a discipline-based introduction to engineering course on improving retention," *Journal of Engineering Education,* vol. 87, no. 1, pp. 79-85, 1998.

[6] M. C. Bell, A. W. Johnson and R. V. Vitali, "Contextualizing Engineering Science Courses by Teaching History and Judgement," in American Society of Engineering Education, Portland, OR, 2024.

[7] R. V. Vitali, "Incorporating History Lessons into a Second-Year Mechanical Engineering Seminar," in American Society of Engineering Education, Portland, OR, 2024.

[8] A. W. Johnson and J. E. S. Swenson, "Open-Ended Modeling Problems in a Sophomore-Level Aerospace Mechanics of Materials Courses," in *ASEE Annual Conference*, Tampa, FL, 2019.

[9] R. V. Vitali, N. Ramo, M. C. Bell, E. Treadway, A. Nightingale, J. Swenson and A. Johnson, "Work-in-progress: Incorporating open-ended modeling problems into undergraduate introductory dynamics courses," in American Society of Engineering Education, Minneapolis, MN, 2022.

[10] J. E. S. Swenson, A. W. Johnson, T. G. Chambers and L. Hirshfield, "Exhibiting Productive Beginnings of Engineering Judgment during Open-Ended Modeling Problems in an Introductory Mechanics of Materials Course," in *ASEE Annual Conference*, Tampa, FL, 2019.

[11] A. W. Johnson and J. E. S. Swenson, "Open-Ended Modeling Problems in a Sophomore-Level Aerospace Mechanics of Materials Courses," in *American Society of Engineering Education*, Tampa, FL, 2019.