ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE
Paper ID #37513

Research seminar designed for undergraduate students builds confidence and access to research opportunities

Andre Montes

Andre Montes is a Ph.D. Student in Mechanical Engineering at the University of Berkeley, California where he uses computational methods to study cell biomechanics and mechanobiology. As a Ford Predoctoral Fellow, he practices his passion for teaching and undergraduate research by leading campus diversity efforts. He holds BS and MS degrees in Mechanical Engineering.

Sofia Ester Arevalo

Sofia is a PhD candidate at UC Berkeley. She is an NSF fellow and an incoming post-doctoral fellow at MIT. She is passionate about equity, diversity and inclusion research and biomedical research.

Grace O'connell

© American Society for Engineering Education, 2022
Powered by www.slayte.com

Research seminar designed for undergraduate students builds confidence and access to research opportunities

Abstract

Upper-division technical electives in undergraduate engineering curricula provide students with an opportunity to learn about various industries within the discipline, which are often aligned well with ongoing research areas conducted by professors in the department. As an undergraduate student, establishing a research area of interest is a first step towards becoming a researcher and is an important part of the pipeline to careers in academia. A semester-long seminar course was offered to undergraduate students in the Mechanical Engineering Department at the University of California, Berkeley to expose students to ongoing research, while providing an opportunity to network with researchers in the department. The course consisted of weekly research talks and discussions. Invited speakers presented a diverse array of research areas and their pathway to research. To assess the course's impact, we surveyed students at the beginning and end of the semester. Approximately half of the students in the course were 1st year students. Survey results showed improved confidence when engaging in research discussions, and better understanding of graduate student research. Additionally, students enjoyed listening to presentations and connecting with graduate students. During the seminar, students learned how researchers and engineers design their experiments and learned about the wide array of applications in mechanical engineering. These preliminary findings can aid faculty and staff developing initiatives to enhance the undergraduate experience in engineering. Future work is needed to understand the long-term impact of participating in such a seminar course (e.g., impact on retention and participation in research).

Introduction

Climate surveys from institutions are shedding light on the lack of diversity and how it affects the student experience. For example, University of California (UC), Berkeley, a large R1 public institution, does not represent the diversity of the state. Diversity and inclusion continue to be important discussion topics at higher institutions, as they affect the current and future students' and faculty's experiences. Many institutions have been working to diversify the pipeline of future faculty candidates through professional development programs (e.g., NextProf and National Science Foundation Advance Programs). However, many talented students from under-represented groups in STEM (i.e., Native American, African American/Black, and Latin American, STEM: Science, Technology, Engineering and Mathematics) "leak" out of the academic pipeline between their undergraduate degree and graduate school. The 2021 American Society for Engineering Education report showed that 20.9% of undergraduate students are from under-represented groups (5.4% and 15.5% for Black and Latino/a students, respectively);

however, only 14% of PhD students are from under-represented groups (4.9% and 9.1%, respectively) [1]. Moreover, many of these students are first generation undergraduates with little background knowledge of graduate school [2].

Diversity in graduate school enrollment can be enhanced by creating research experiences for minority undergraduates [3]. Moreover, undergraduate research experiences are pivotal to training the next generation of scientists and engineers. Participating in research as an undergraduate student has been shown to increase student confidence, provide a deeper understanding of the field, improve understanding of conceptual connections, improve critical thinking and problem solving skills, increase graduation rates, and increase the likelihood of students attending graduate school [4–6]. In particular, undergraduate research experiences provide personal and professional gains while enhancing technical and communication skills [7].

However, accessibility to research opportunities outside of official summer research programs can be a challenge that deters students. A study by Madan et al. showed that undergraduate students feel overwhelmed and uninformed about how to obtain research positions [8]. Furthermore, accessing research opportunities is exacerbated by a lack of guidance in navigating academic spaces, a particular challenge for first generation students [2]. These factors, and more, may contribute to low participation rates of undergraduate students participating in research. For example, from Spring 2019 to 2020 only 3.3% of mechanical engineering (ME) undergraduates were enrolled in independent research at UC Berkeley, an R1 institution.

Figure 1 illustrates one common pathway to becoming an undergraduate research scientist, where an essential first step is being aware of research areas. Students may discover research areas through peer and family networks [3] or technical electives. Once students have identified their research interest, they can begin seeking research positions through informal methods such as "cold emailing" professors, participating in lab tours, tapping into their peer network, or interacting with instructors during class. Some institutions have more formal methods to engage students in research by incorporating it as part of a degree requirement, or providing a platform to connect students and researchers. Lastly, research programs, such as NSF's (National Science Foundation), REUs (Research Experiences for Undergraduates), Undergraduate Research Apprenticeship Programs, and SURFs (Summer Undergraduate Research Fellowships), provides an opportunity for uninterrupted research experiences that allow for more in-depth learning. Once students have successfully gained admittance to a research project, they can work alongside researchers. Through proper guidance and mentorship, a student can develop their scientific identity. Furthermore, individualized faculty-student interactions has a positive impact on a student's decision to pursue graduate school [9].

Figure 1: Pathway to becoming a researcher

Unfortunately, not every student has access to a network of researchers or has been exposed to a potential research pathway through their coursework. Thus, we developed a seminar course to provide students with an opportunity to learn about research, what it means to be a researcher, and highlight research activity in the department. In this course, we invited current researchers (graduate students and faculty) to discuss their ongoing technical work and share their pathway in academia. Seminars were designed to demystify research at an R1 institution, bring the undergraduates' attention to the diverse disciplines within ME, and provide context for how undergraduate research can impact their career after graduation. We hypothesized that introducing students to diverse research topics in a low-stakes setting would increase an understanding of the variety of research topics and provide a clear avenue for entering into a desired research field.

Research Seminar Implementation

To test our hypothesis, we developed a one-unit research seminar course in ME titled, "Finding Your Research Pathway" (FYRP). The course was first offered as a virtual course during the Spring 2021 semester. The research seminar met online every other week for 50 minutes (full semester = 14-weeks). 11 undergraduate students enrolled, primarily juniors and seniors. The objectives of this course were to (1) broaden students' perspective of content taught in the department through technical electives, (2) build student confidence for engaging in technical discussions about research, and (3) provide a space for students to interact with graduate student researchers. These objectives were used to design the course, and the impact was assessed through survey responses (Figure 2).

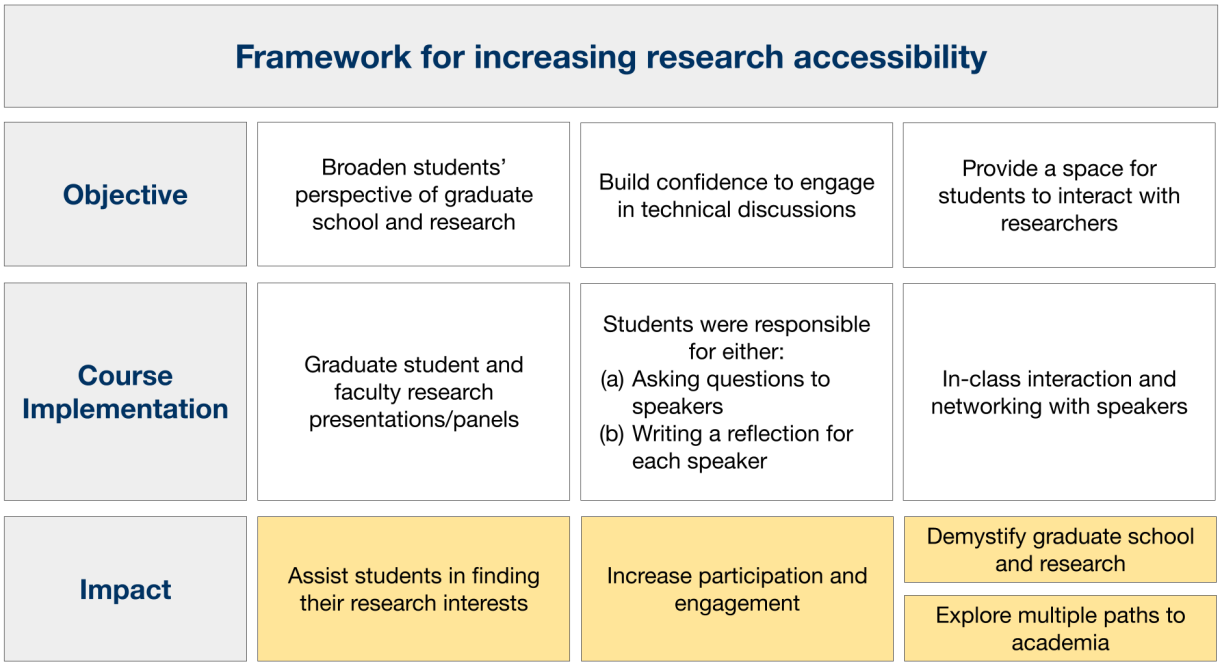

Figure 2: Research seminar framework including objectives, implementation, and impact.

During the first offering of FYRP, 20 ME graduate students were invited to present their career

pathway and ongoing research. In each session, two to three graduate students presented their work in 10-15 minute presentations. To receive course credit, undergraduate students were responsible for contributing to research discussions by asking questions or writing a one-paragraph reflection on each presentation.

We evaluated the impact of FYRP by administering a pre- and post-course survey. The results indicated that undergraduate students had (1) an improved awareness of on-going research, (2) increased comfort in asking about research positions, and (3) heightened confidence when engaging in research discussions. Students requested to include 'graduate student life' as part of the discussions. Additionally, students requested more time with professors to obtain a broader perspective of research within the ME department while learning about how to get involved in undergraduate research. Student feedback was used to modify the course structure for the following semester (Fall 2021) and to conduct an IRB-approved research study (Protocol #2021-07-14502).

The Fall 2021 offering of the course was in-person and 19 undergraduate students enrolled. We expanded the seminar to meet weekly and invited 7 professors and 15 graduate students to present their career pathways and current research areas (Table 1). In doing so, we provided more opportunities for undergraduate students to network with graduate students and professors during Q&A sessions. The course met weekly for 50 minutes and the presentation format varied from week to week. There were three presentation formats based on the speakers' style and time limit.

- Short form: 10 minute presentation followed by 15 minutes of Q&A per speaker
- Long form: 25-30 minute presentation followed by 20-25 minutes of Q&A
- Panel discussion: 5 minute presentation per panelist followed by open 20-25 minutes of Q&A for all panelists

Undergraduate students were given the option to receive course credit by either (1) asking two questions during class or (2) writing a one-paragraph summary for each speaker. Students were able to miss up to two assignments and still receive a passing grade. Grading was pass/fail for all students.

Both pre- and post-course surveys were administered online and students were asked to complete them outside of the classroom. The pre-course survey was administered prior to the first session. After asking for consent and basic demographic data (major, gender, race, and first generation identity), the following statements were judged by the participants using a 5-point Likert scale from "Strongly Disagree = 1" to "Strongly Agree = 5:"

- I feel like I have been encouraged to partake in research projects
- I have started to actively seek research positions
- I have participated in undergraduate research
- I feel confident in engaging in research projects
- I have a good understanding of graduate student research

Table 1: Research seminar schedule for Fall 2021

Week	Speaker(s)	Presentation Format	Research Area
1	Professor 1	Long-form	Tissue Biomechanics
2	Grad Student 1	Short-form	Clinical MEMS/Nano
	Grad Student 2	Short-form	Heat Transfer
3	Professor 2	Long-form	Robotics & Controls
4	Grad Student 3	Panel discussion	Energy Sciences
	Grad Student 4	Panel discussion	Materials Science
	Grad Student 5	Panel discussion	Materials Science
5	Professor 3	Long-form	Fluid Dynamics
6	Grad Student 6	Panel discussion	Design (Experimental)
	Grad Student 7	Panel discussion	Design (Experimental)
	Grad Student 8	Panel discussion	Design (Computational)
7	Professor 4	Long-form	Mechanics
8	Grad Student 9	Panel discussion	Mechanics
	Grad Student 10	Panel discussion	Fluid Dynamics
	Grad Student 11	Panel discussion	Fluid Dynamics
9	Professor 5	Long-form	Energy Sciences
10	Grad Student 12	Short-form	Control Theory
11	Professor 6	Long-form	Clinical MEMS/Nano
12	Grad Student 13	Short-form	Tissue Biomechanics
13	Professor 7	Long-form	Manufacturing
14	Grad Student 14	Short-form	Bio-inspired Materials
	Grad Student 15	Short-form	Clinical Kinematics

- I have a good understanding of graduate student life
- I intend to go to graduate school
- I feel confident in forming a graduate school application
- I have access to a PhD/MS holder who I can ask about the graduate school application process
- I belong at UC Berkeley
- I am confident in my choice of desired research field
- I feel comfortable asking professors or graduate students for research positions
- I feel confident engaging in research discussions
- I am well-acquainted with the ongoing research in the Department of Mechanical Engineering at UC Berkeley

The survey was also emailed to all ME undergraduates through the departmental newsletter. Respondents were asked if they had participated in FYRP; those who responded affirmatively were screened out and unable to complete the survey. Students that did not participate in FYRP served as a comparative control group.

A post-course survey was administered to students enrolled in FYRP at the end of the semester. The same questions were asked from the pre-course survey with the following additions:

- After participating in the course, I am more likely to apply to graduate school (Likert scale)
- Would you recommend this seminar to your peers? (Yes/No)
- Has this course helped you identify or narrow your research interests? (Yes/No)
- What was your favorite part of this course? (Open response)
- What feedback would you give the instructors to improve the next offering of the course? (Open response)

Responses from each Likert scale question were tested for normality using the D'Agostino-Pearson test. Post-course survey responses were compared to pre-course survey responses using a paired t-test for each question. Pre-course survey responses were compared to the control group using unpaired t-tests.

Research Seminar Outcomes

All 19 students in the course passed by completing the required assignments and 16 students provided responses to the pre-course and post-course survey. 3/16 students were female (Table 2), which is aligned with the department average of 23% (department average for incoming class of 2025). Half of the cohort was first year students. 15/16 undergraduates had not yet entered their fourth year, with one student being in their fifth year. The course composition by race or ethnicity was comparable to the department average for Asian or Asian descent students (department average = 38%) and students from under-represented groups (25%; Table 3). Demographic data from the central campus does not delineate students as being bi- or multi-racial. The four Latin American students identified as being first generation college students and were the only self-reported first generation students in the course.

Table 2: ME Undergraduate Students by Year

		All	1st year	2nd Year	3rd Year	4th Year	5th Year
Seminar (n=16)	M	13 (81%)	6	3	2	0	1
	F	3 (19%)	2	0	1	0	0
	NB	0	0	0	0	0	0
Control (n=40)	M	19 (47.5%)	3	5	7	4	0
	F	20 (50.0%)	4	3	8	5	0
	NB	1 (2.5%)	1	0	0	0	0

M: Male, F: Female, NB: Non-binary

40 ME students from the general student body responded to the survey request, composing the control group (Table 2). The percentages of different races were similar in the control and seminar groups (Table 3). However, the ratio of male to female respondents between the two groups did not align. Both the control group and course advertisement were sent to the ME undergraduate population by the same staff member. Additionally, the course was advertised to

various affinity groups across the College of Engineering and was included in the College of Engineering newsletter. Even with the increased advertisement of the course, the control group's female response rate far exceeded that of the seminar group (Table 2).

Table 3: ME Undergraduate Students by Race

Race	**Seminar (n=16)**	**Control (n=40)**
African American / Black	0	0
Asian or Pacific Islander	7 (43.75%)	17 (42.5%)
Latin American	4 (25%)	9 (22.5%)
White or Caucasian	2 (12.5%)	9 (22.5%)
Biracial or Multiracial	2 (12.5%)	5 (12.5%)
Abstained	1 (6.25%)	0

FYRP was open to students of all years and majors in the College of Engineering; however, all enrolled students were from the ME Department. This was likely a result of FYRP being listed as an ME course, rather than general engineering, and the course description indicating that speakers would be from the ME Department. The higher enrollment of early-stage undergraduate students could indicate that these students are more available to exploring different topics in ME or may be a result of how students consume information during their time in college (e.g., official communications versus peer network). Students opting to take the course earlier in the degree curriculum are expected to receive the greatest benefit by having more time to pursue undergraduate research. However, it is expected that the course is still beneficial to later-stage students (i.e., 3rd year and beyond) because of the increased exposure to different applications of ME and networking. When asked about their favorite part of the course, the fifth year senior commented:

Student 1*: My favorite part of the course was listening to all the different professors and grad students share their research. I was not aware of a lot of the research going on at UC Berkeley, but this blew my mind. Being a senior, I really wish I would have taken this class a lot sooner because I feel like I would have greatly benefited from this and would have reached out for undergraduate research a lot sooner.*

While this student had previously participated in undergraduate research, they also acknowledge that they would have benefited from being introduced to a broad range of applications early into their academic career. As such, offering this course to first or second year undergraduate students may result in higher participation rates in undergraduate research. However, a longitudinal study would be needed to evaluate the impact on research participation as a result of participating in FYRP.

According to the post-course survey, 12/16 students in FYRP either agreed or strongly agreed (75%) about intending to go to graduate school after taking this course (Figure 3a). In comparison, 57.5% of students in the control group agreed or strongly agreed to go to graduate school 3b). While the majority of students in the seminar course are interested in pursuing graduate school, 94% of the students were unaware of the ongoing research in the department at the start of the semester (Figure 4 - green bars, first question). This was compounded by low

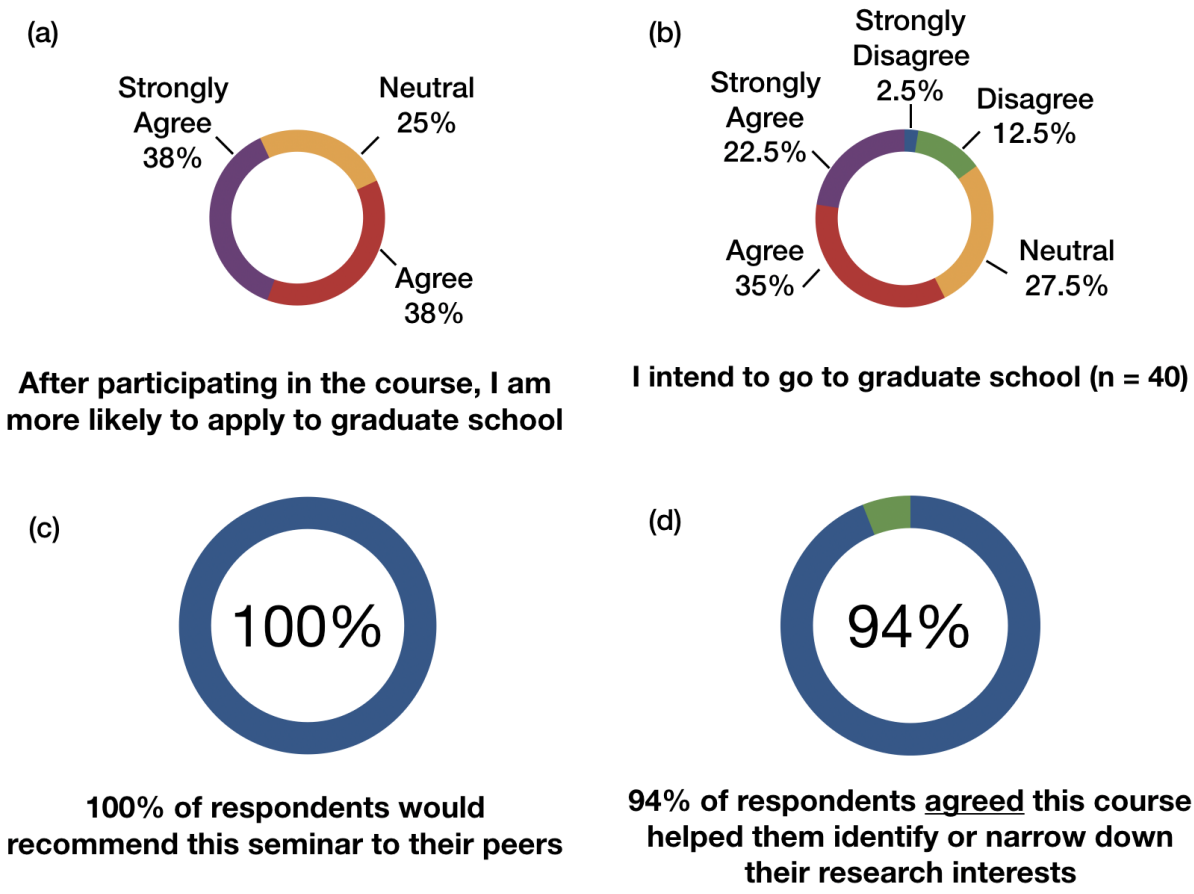

Figure 3: (a) Breakdown of student responses to "After participating in the course, I am more likely to apply to graduate school". (b) Breakdown of student responses in the comparative control group to the question, "I intend to go to graduate school." Percentage of students that (c) would recommend FYRP to their peers and (d) felt FYRP helped them identify or narrow down their research interests.

confidence when engaging in research discussions and seeking out research positions (Figure 4). These results highlighted how the low-stakes space in FYRP allowed students to practice discussion and networking skills with graduate students and professors. In turn, the undergraduates could begin to refine their understanding of graduate study components such as research and graduate student life.

All 16 students responded in the post-course survey favorably to recommending FYRP to their peers (Figure 3c). Nearly all students (15/16 or 94%) stated that the course helped them narrow their research interests (Figure 3d), which can also be applied to selecting upper-division technical electives.

One student did not find the course helpful in narrowing down their research interests, but did note that their favorite part of the course was "*hearing about a variety of research topics.*" They also reported feeling confident in engaging in research projects, but still lacked confidence in their choice of research area.

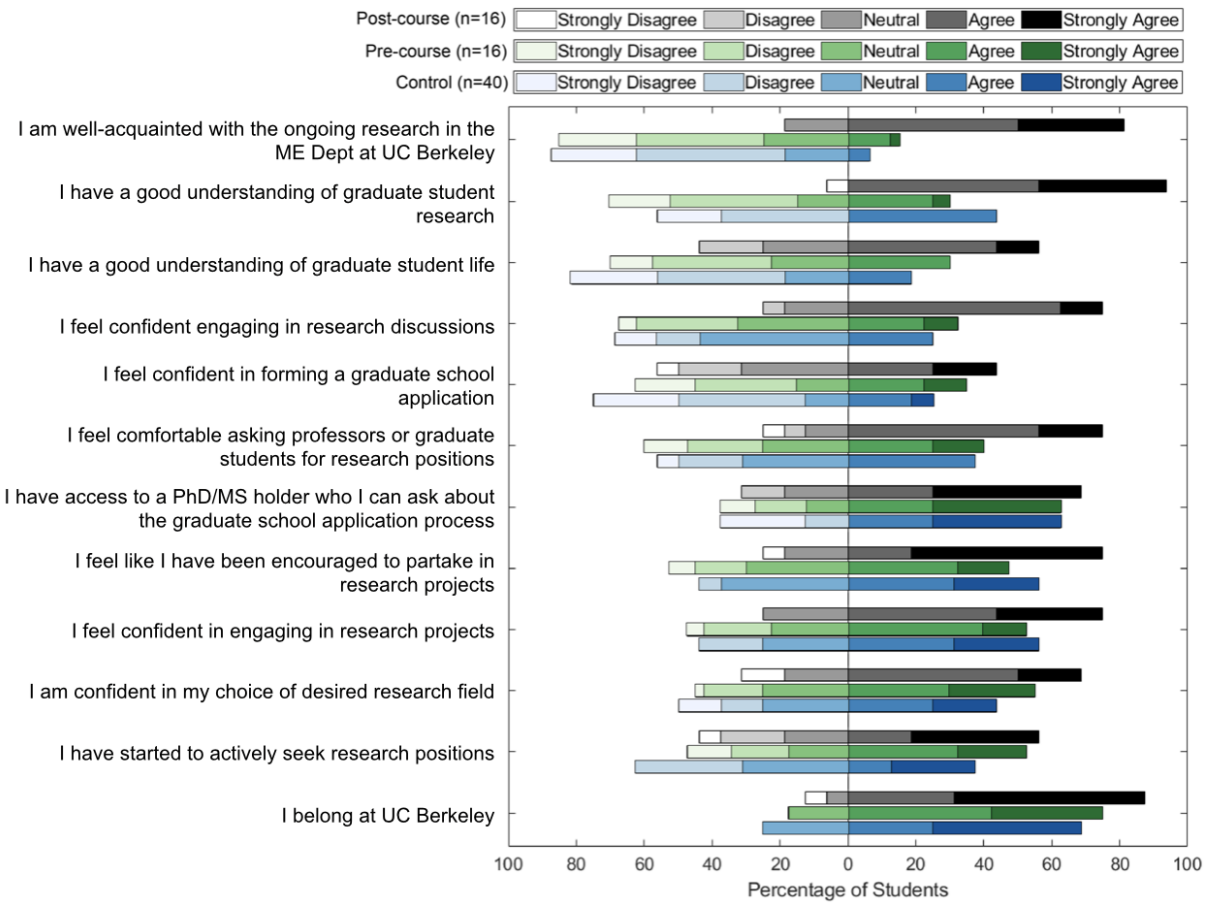

Figure 4: Distribution of survey responses from the pre-course (grayscale), post-course (greenscale), and control surveys (bluescale). Questions are ranked in descending order from greatest difference in mean scores between pre- and post-course response.

Responses from the pre- and post-course survey were compared to assess changes over the semester. There was a positive, statistically significant effect on students' understanding of ongoing research in the department, perspective of graduate school, and confidence in engaging in research discussions (Figure 5, see first four categories).

Survey results showed that the course was valuable even for students that have already participated in undergraduate research by providing space to explore other topic areas. Four of the five students that had previous experience participating in research indicated that the course helped them narrow their research interest, with one student citing the diverse coverage of research topics as their favorite component of the course:

***Student 2**: I loved the variety of researchers, I didn't realize how many applications mechanical engineering has in biology or other areas.*

In the survey, we provided an opportunity for students to share their favorite part of the course, giving insights into course effectiveness. Responses from 15 students spanned across multiple areas and were grouped based on the theme of their comment. Thematic areas included the variety

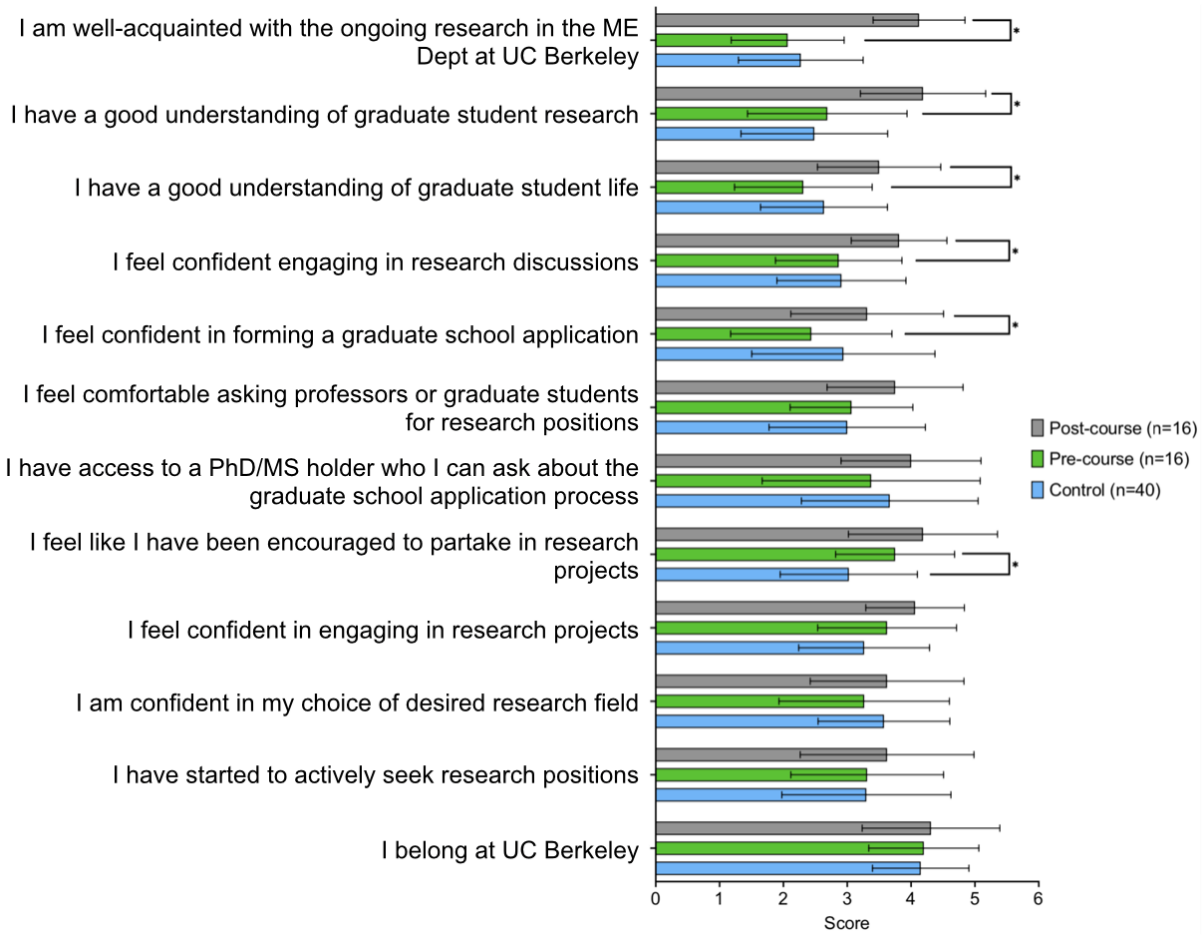

Figure 5: Mean ($\pm$ S.D.) of survey responses using the Likert scale where 1 is Strongly Disagree and 5 is Strongly Agree. *$p < 0.05$

of research topics (6/15), networking and scientific discussion (6/15), and community connections (3/15). Comments from Student 1 and 2, which were focused on the variety of research topics, are provided in the text above, while sample comments from their classmates are listed below.

Variety of research topics:

Student 3*: Just hearing about the many research projects in the ME department at UC Berkeley and hearing about how these researchers went about designing their experiments/projects*
Student 4*: My favorite part of this course was having a glimpse of the research that current graduate students and professors are doing in their time outside of the classroom.*

Networking and scientific discussion:

Student 5*: Being able to ask speakers specific questions about their research.*
Student 6*: Interesting research topics covered by speakers, including graduate students and professor. Ability to ask questions about research and receive detailed and insightful answers.*

Community connections:

Student 7*: Meeting different professors and students with a variety of stories about how they got to do the research that they do. Seeing their career play out serves as a guide.*
Student 8*: I enjoyed listening to speakers who had similar interests as me and hearing about all of the cool projects they got to do.*

This study is not without limitations. The students' responses are self-reported and could be biased since they expect to garner a better understanding of the purpose of research and graduate school. Furthermore, the sample size (n=16) is a small case study, particularly when compared to the total ME undergraduate population of 731 at the institution. Of the 12 students who were not first generation students, it is unknown whether their parents obtained graduate degrees. This could partially explain the large interest in graduate school at the start of the course, but no data on parental education was acquired. Moreover, the sample size for URM students (n=4) within the class was not sufficient to make any claims on the effectiveness of FYRP on URM students. A longitudinal study that includes a higher sample size of URM students enrolled in FYRP would evaluate how exposure to research influences their decision to pursue graduate school. Additionally, longitudinal data studying the effect of the course on undergraduate research participation is warranted. The current IRB-approved protocol allows for a 6 month follow-up asking undergraduates who took the course about their participation in research after the course. If this course increases undergraduate research participation, then the course may also serve as a gateway for reducing attrition rates and fueling the graduate school pipeline since undergraduate researchers are more likely to remain in the undergraduate program relative to their peers who do not pursue research [10, 11].

Conclusion

Survey results from this pilot course provides a promising narrative that weekly ME research seminars by graduate students and professors has a positive impact on the undergraduate experience. As such, 100% of respondents from the seminar course would recommend this course to their peers and 94% of respondents agreed this course helped them identify or narrow down their research interests. Most importantly, students expressed an increased understanding of research within ME, and the course provided an opportunity to develop networking skills, gain social capital, and inspired the pursuit of undergraduate research and graduate school. These results ultimately confirm the proposed hypothesis. By introducing a wide array of research topics within ME, students are exposed to application areas they may not have considered previously. In conclusion, providing a platform for graduate students and faculty to share their 'pathway to academia' can motivate undergraduate students to become more engaged in academic research. Long-term follow up studies are necessitated to understand whether the increased interest in a particular research area translates to involvement into that particular research area.

References

[1] J. Roy, A. Erdiaw-Kwasie, C. Stuppard, and T. King, "Engineering by the numbers," in *American Society for Engineering Education*. American Society for Engineering Education, 2021, pp. 1–110.

[2] P. Wickware, "Along the leaky pipeline," *Nature*, vol. 390, no. 6656, pp. 202–203, 1997.

[3] L. Tsui, "Effective strategies to increase diversity in stem fields: A review of the research literature," *The Journal of Negro Education*, vol. 76, no. 4, pp. 555–581, 2007.

[4] P. R. Hernandez, "Sustaining optimal motivation: A longitudinal analysis of interventions to broaden participation of underrepresented students in stem," *Journal of Education Psychology*, vol. 105, 2013.

[5] S. Laursen, A.-B. Hunter, E. Seymour, H. Thiry, and G. Melton, *Undergraduate research in the sciences: Engaging students in real science*. John Wiley & Sons, 2010.

[6] L. Zhu, C. Eggleton, R. Ma, L. Topoleski, and D. Madan, "Establishing the need to broaden bioengineering research exposure and research participation in mechanical engineering and its positive impacts on student recruitment, diversification, retention and graduation: Findings from the umbc me s-stem scholarship program," *Journal of Biomechanical Engineering*, vol. 142, no. 11, 2020.

[7] E. Dolan and D. Johnson, "Toward a holistic view of undergraduate research experiences: An exploratory study of impact on graduate/postdoctoral mentors," *Journal of Science Education and Technology*, vol. 18, no. 6, pp. 487–500, 2009.

[8] C. R. Madan, B. D. Teitge *et al.*, "The benefits of undergraduate research: The student's perspective," *The mentor: An academic advising journal*, vol. 15, pp. 1–3, 2013.

[9] J. C. Hearn, "Impacts of undergraduate experiences on aspirations and plans for graduate and professional education," *Research in Higher Education*, vol. 27, no. 2, pp. 119–141, 1987.

[10] S. H. Russell, M. P. Hancock, and J. McCullough, "Benefits of undergraduate research experiences," *Science*, vol. 316, no. 5824, pp. 548–549, 2007.

[11] M. T. Jones, A. E. Barlow, and M. Villarejo, "Importance of undergraduate research for minority persistence and achievement in biology," *The Journal of Higher Education*, vol. 81, no. 1, pp. 82–115, 2010.