Board 131: Investigating the Impact of a Mechanical Engineering Undergraduate Research Experience on Student Learning (Work in Progress)

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Introduction

In the U.S., widespread support and funding for undergraduate research programs has existed since at least the 1950s. The National Science Foundation developed a program supporting undergraduate research in universities; the Undergraduate Research Participation (URP) program in 1958, which was cancelled in 1981, but was later relaunched in 1987 as the Research Experiences for Undergraduates (REU) [1], [2]. The Council on Undergraduate Research has also been pivotal in the development of structural programs to promote research in predominantly undergraduate institutions [2]. This has led to an increase in undergraduate research programs at different universities over the last 35 years.

Several models for undergraduate research programs exist, in addition to REUs. These models include capstone experiences, senior theses, internships and co-ops, course-based undergraduate research experiences (CURES), wrap-around experiences, bridge programs, consortium/project-based programs, community-based research programs [1], [3]. However, most of these programs are relatively short-term (i.e., limited to one to two semesters) and thus constrain how deeply students can delve into their research.

Earlier studies have shown that participating in research as an undergraduate student can help students explore their interest in graduate school [4], develop research skill [5], and improve learning outcomes [6]. Further, undergraduate research has been shown to help students attain higher levels of competence in STEM, thus positioning them to be strong contributors to the STEM workforce [7]. Providing undergraduate engineering students co-curricular learning opportunities to deepen their knowledge of recent STEM advances will enable them to become engineers who are primed to innovate and push the boundaries of existing knowledge. It also provides students access to a research community for interaction with other researchers [8] and opportunity to engage in active learning [9].

Schuster & Birdsong [8] report challenges that come with undergraduate research experiences, namely that most traditional research institutions prefer to engage doctoral students who can be on the project for four to six years. However, there is a growing shift and demand for undergraduates to be involved in research as evidenced by the sustained popularity of undergraduate research experiences. But most of the undergraduate research experience dominating the research space is in STEM disciplines and are mainly conducted during the summer with a duration of 10 –12 weeks [10]–[13].

In this paper, we explore a longer-term (i.e., more than one summer or semester) undergraduate research experience at a R1 institution. The purpose of this paper is to pilot entry and exit interview protocols with the 2022-2023 cohort of undergraduate student researchers who conduct a year-long research project under the supervision of a faculty member in Mechanical & Materials Engineering. This work-in-progress paper will report preliminary findings from the

entry interview protocols in order to validate the instruments and inform future data collection efforts. In order to begin to understand students' experiences and inform future instruments, we pose the following research questions:

> RQ1: According to students, what do they expect to learn over the course of a year-long research experience?
>
> RQ2: According to students, what did they learn over the course of a year-long research experience?
>
> RQ3: According to students, what challenges did they face over the course of a year-long research experience?

Methods

This paper uses a combination of a priori and in vivo coding on qualitative, semi-structured interviews with 12 participants in a long-term undergraduate research program. Appropriate institutional ethics approval was obtained prior to data collection.

Participants and Setting

The participants of this study are 12 undergraduate students in the department of Mechanical and Materials Engineering at a land-grant, research-intensive university in the mid-west United States. The participants, comprising of eight males and four females, were in classes between sophomore and senior year of their engineering major and were enrolled in at least three undergraduate courses each semester during the 2022/2023 academic year. Each of the students were part of a privately funded program that allowed them to participate in undergraduate research in collaboration with faculty members of the department of Mechanical and Materials Engineering. The students were paid for 10 hours of research per week throughout the academic year. Due to budget constraint, the program is only able to fund 16 students in an academic year after a competitive selection process, of which 12 of these students consented to participate in this study. The goal of the undergraduate research program is to enhance student outcomes, including retention, academic success, and the likelihood of pursuing graduate studies.

Data Collection

An entry semi-structured interview protocol was developed for this study and probed at issues surrounding student's interest in research, expectations from research, experiences gathered during the research, and intended career path upon graduation. The students were specifically asked what they hoped to gain from participating in the research projects that they were engaged in. Interview questions that are relevant to the analysis done in this paper are included in Table 1. The 30-minute interviews were conducted via Zoom or in-person, depending on the choice of participants, within the first 4-weeks of the students' research experience. Interview data were recorded with the permission of the participants and transcribed via a transcription software. Notes were also taken by the researchers during the interviews, and participants were informed that they could refrain from answering any question that they did not feel comfortable with. They

were also informed that participating in the interview was voluntary and it would have no impact on their course grades. The researchers reviewed the transcribed data line by line and corrected the transcript against the recordings. Each of the researchers went through the transcribed data to ensure that the interview responses were adequately captured.

Table 1: Relevant Questions from Interview Protocol

1. Why did you decide to apply to do research as an undergraduate student?
2. What do you hope is the outcome of your research?
3. What are you hoping to gain from this research experience?
4. How is your research going so far?
5. How do you plan to fit your research into your schedule?

Data Analysis

A priori coding [16] was used to identify what students expected to learn, what they had learned already, and what challenges they had faced. In vivo subcodes were then applied in order to identify what kinds of learning occurred and challenges that were encountered. The subcodes within each primary code were analyzed and grouped in order to identify themes that answered each research question. Coding was conducted primarily by Author 1, and coding checks were conducted by Author 2.

Limitations

This study was conducted in one department at one university and hence the findings are not intended to be generalized to the larger population. Rather, the findings can be transferred to other contexts by researchers and practitioners who can compare their context to the context in which this study was conducted. Next, this study only captures students who were selected for this research opportunity, which are high-achieving students by definition. Additionally, this study is a pilot study with limited data which constrained the direction and scope of the study. While the goal of our larger project is to understand the impact of a long-term undergraduate research experience in comparison to short-term experiences, this paper is not able to make such claims.

Findings

Preliminary findings from the entry interview conducted are presented in this section. In order to answer the research questions, we present themes that emerged related to students' expectations of what they would learn, what they had learned thus far, and what challenges they had encountered thus far.

Expectations of Learning

The dominant theme in students' responses to their learning expectation while engaging in research was to gain experience. Experience in this context was grouped into research, hands-on (practical) experience, and career experience. Eight of the 12 students interviewed said that

engaging in research will provide them with the exposure to gain engineering experience that would help in their decisions to pursue graduate school or advance in their respective careers without graduate studies. They felt that this would adequately prepare them for jobs in industry as it would give them a competitive edge during job recruitment. For practicality and hands on learning experience, the students hoped that engaging in research will enable them to develop practical skills like mechanical testing and experimental set-up. Computational skill was also another hands-on learning skill that the students hoped to get by engaging in research, one student was quoted as saying they want to learn 3D printing skill, another hoped to learn simulation while three students hoped to learn computer programming.

Other students wanted to broaden their knowledge of science and engineering beyond what was taught in classrooms. One student reported having some knowledge deficiency in material science and hoped that engaging in related research would be of help. However, another student reported not having any exact expectation by engaging in research but was driven by curiosity and quest for knowledge.

Realities of Learning

Computational skills and mechanical testing were two common themes that were prevalent in the analysis of what the students had learned over the duration they had engaged in research, as this came up seven and five times respectively in the 25 codes analyzed. The students acknowledged learning a lot of computer programming skills, code writing and use of software such as MATLAB, Excel and imaging software. The students also reported learning mechanical testing, a very vital skill in research design, which began with the students first learning how to do a laboratory set up from scratch, a skill which they had not been exposed to in traditional classroom settings.

Research writing skills was also a prevalent theme in students' reflections of their learning. Students reported learning new methodologies of research and report writing from engaging in research. Some students gained knowledge on how to conduct a literature review search, writing of an IRB proposal, designing a research poster, while two students responded that they learned communication skills as a result of doing research with members of a team. The students were just a few weeks into their research and acknowledged being excited about new things that they were learning. One student said, "I never believed that I could learn the things that I have been exposed to through research of just a few weeks."

Challenges

Time emerged as a common challenge that participants faced. Three of the 12 responses analyzed showed that combining research into students' schedule posed a significant challenge. Students who discussed time-constraints were often engaged in some other form of activities outside of classroom engagements and research or reported conflicting schedules with lab-mates. The students, however, said that they were still able to achieve their weekly commitment of 10 hours by having a flexible schedule. Students reported building their research schedule around their coursework schedule, often working after class hours and on weekends. Another student

was considering letting go of one of their extracurricular commitments in the next semester to have more free time to engage in research.

Unsuccessful attempts emerged as another common challenge that participants faced. Three of the students expressed frustration at the initial failures experienced at the beginning of the research which led to repetitive processes. However, most of the students expressed optimism that things were getting better and hoped that these setbacks would not affect project deadlines. They said that by continuous retrials and seeking help from their advisors, graduate students, and online resources and literature, they were able to overcome some of these initial setbacks.

Conclusion

In this study, we can see from preliminary investigations the benefits of participating in undergraduate research. While this is still an ongoing study to investigate the impact of the year-long research experience, it is our conclusion from the results generated that the interview protocol is suitable for this study and captures the context it is intended to measure. However, the interview protocol for the exit interview for the 2022-2023 cohorts and entry and exit interviews for subsequent cohorts will be modified to include a question on ‘what challenges, if any, did the students experience during the study?’ and ‘how were they able to overcome the challenges?’ These questions will help guide participants in sharing detailed aspects of their experiences not captured by the initial interview protocol. Future work on this study will involve analysis of the exit interview to capture the full experience of the participants and assess the impact of the year-long research experience.

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