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Infusing an Entrepreneurial Mindset in Undergraduate Researchers through Faculty Development

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Abstract

Undergraduate research experiences are widely recognized for their significant benefits, yet undergraduates often require more hands-on guidance than graduate students. Equipping them with entrepreneurial mindset (EM) attributes - such as setting goals, framing research questions, and practicing resilience - is crucial for fostering their confidence in research. Since these traits are most effectively modeled by research advisors, our study focuses on enhancing faculty development programs.

A team from five universities designed a package of videos and activities for faculty workshops to promote discussions on integrating EM into research mentoring. We administered a benchmark survey to assess faculty motivations, interests, and challenges in supervising undergraduates, finding that most respondents valued incorporating undergraduate researchers into their labs, but were concerned about short research engagements and a perceived low return on investment.

Our workshops encourage best-practice sharing and community-building among faculty, addressing common issues and supporting more productive mentorship strategies. A follow-up survey, though limited in response rate, revealed that faculty who attended the workshops were more likely to "strongly agree" that undergraduate research adds value and more frequently asked students to consider the broader impact of their projects. Future data collection will refine our understanding of how these workshops influence undergraduate research mentoring.

Keywords: undergraduate research, entrepreneurial mindset, faculty mentoring development

Introduction

It has been clear for decades that a research experience for science, engineering, and mathematics undergraduates is a high-impact practice that is valuable to the country's education and research activities, as evidenced by continuous support for Research Experiences for Undergraduates (REUs) since 1987 from the U.S. National Science Foundation [1]. The benefits to the undergraduate students are myriad [2], ranging from the obvious benefits of producing students who are better-informed at decision making as they launch their careers or embark on advanced study, to the more subtle benefits such as enhanced STEM graduation rates for some under-represented minorities [3], and improved motivation, confidence, academic performance, and self-management skills [4]. Graduate students often serve as mentors to undergraduates engaged in research, which can enhance access to mentorship while providing undergraduates with a more peer-like mentoring experience [5]. For a faculty member directing research, engaging their graduate students in research with undergraduates offers the graduate students experience and training that can better inform and equip them as they make decisions about whether and how to launch an academic career. However, while overall productivity in the research laboratory is likely to increase by involving more individuals in the enterprise, productivity based on some measures (e.g., rate of publication in archival journals) may or may

not increase. It is easy to imagine a scenario in which time devoted by faculty and graduate students to educating an undergraduate in the laboratory, at least temporarily, undermines other laboratory activities.

While the overall benefits of engaging undergraduates in research are clear, compelling, and borne out over time and at scale, the individual experiences of the involved undergraduate students, graduate students, and faculty face some risks and challenges [6]. Some of these risks are from simple matching challenges: for example, the challenge of placing undergraduates in the right place (where they have an interest) at the right time (when they are prepared). However, little reflection is needed to recognize that the matching exercise is very challenging. Most engineering curricula provide some technically specialized training in the junior year, but most of it in the senior year, and the senior year is often the most time-demanding year for students. Thus, for most students, the window of time for being aware of their interests and equipped to act on those interests is only open for a relatively short time. Exposing students to research and providing relevant training can maximize that time [7] [8]. However, faculty can also be highly risk averse when it comes to the scholarly productivity of their lab, and they must be convinced that the overall output of their lab, measured in a way aligned with their values and the institution's priorities, will benefit before they will commit to undergraduate research [6] [9].

The project on which we now report has been focused on developing materials and methods to support: (i) the early exposure of undergraduates to research; (ii) research training for undergraduates; and (iii) faculty development for undergraduate research. Through the early exposure to research, we hope to make undergraduates aware of the nature of research and research opportunities earlier than they otherwise would be exposed spontaneously. We hope to generate interest and excitement, so students can approach course selection, coursework, and relationships with faculty with a potential interest in research in mind. Through this activity, the aim is to equip students with the knowledge and confidence to be ready for the window when they can best leverage undergraduate research. Our second activity to support research training for undergraduates is aimed at training students who have a clear interest or active participation in research. Undergraduates with early training in research are better equipped to understand their interests and abilities; moreover, having such training in place can mitigate faculty risk and move the faculty focus away from the risks, and toward potential benefits. Our third activity, faculty development, is focused on making clear that the benefits of engaging undergraduates in their research clearly outweigh the costs, and making the case that best practices exist to mitigate risk and maximize benefits to their lab and their graduate students.

This paper focuses on reporting our effort towards faculty development programs. A collaborative team from five universities developed a set of workshop materials that include videos and activities for faculty workshops designed to foster discussion on integrating an entrepreneurial mindset in research mentoring. A benchmark survey was distributed to faculty to assess their interest in involving undergraduates in research, their motivations, and the challenges they face.

These workshops allow faculty members to share best practices, build a support community, and exchange resources and tools to enhance mentoring. Key discussion topics include strategies for attracting and engaging students, sparking students' curiosity, fostering teamwork, helping

students recognize their contributions, and encouraging students to explore the broader impact of their work as important contributions to future technology to benefit society.

A follow-up survey was conducted to evaluate the impact of these activities, assessing whether they improved faculty-student interactions and enhanced research productivity. Faculty were also invited to submit a short report detailing how they updated their mentorship practices to integrate the workshop tools or other aspects of entrepreneurial mindset. This faculty development initiative aims to support faculty to help students bridge the gap between their skillset and mindset, ultimately fostering a research environment that inspires and empowers students to achieve success.

Methodology

Research Design and Participation

The collaborative research project was led by a group of faculty from five diverse universities, including Baylor University, Georgia Institute of Technology, Lawrence Technological University, Rose-Hulman Institute of Technology, and University of Illinois at Urbana-Champaign.

The workshops were conducted both as standalone faculty development activities and in conjunction with existing departmental or school-wide programs, depending on the location. Many of these venues are open to all faculty, although we specifically recruited participants from engineering and computer science disciplines to participate in the workshops.

Workshop Development and Materials

The overall goals of the faculty development workshops are to 1) improve faculty engagement in undergraduate research experiences, and 2) integrate an entrepreneurial mindset (EM) into research mentoring. To achieve these goals, we developed two main workshops addressing how to empower students with an entrepreneurial mindset in research [10]: *How to Involve Undergraduates in Research* and *Why Involve Undergrads in Research*. Both workshops build on the three principles of the entrepreneurial mindset - “curiosity”, “connections”, and “creating value”, as defined by the Kern Entrepreneurial Engineering Network (KEEN) [11] - and highlight how integrating these principles into mentorship can improve student mindsets and motivation, leading to more productive research experiences.

The workshops consist of an introduction to the resources developed through this collaborative project, followed by guided discussions, and/or a short activity. Snippets of the early exposure and student research training videos were shown to demonstrate the materials available for faculty to use with their students. The activities are designed to introduce faculty to the concepts of EM and provide opportunities for faculty to discuss and share best practices with each other.

These workshops are designed specifically for faculty mentors, rather than the students themselves, providing an opportunity for faculty to reflect on the best mentorship practices to motivate and maximize the productivity of their undergraduate researchers. Unlike other training programs that might be offered through regular REU workshops, these workshops are unique in

their focus on leveraging key elements of the entrepreneurial mindset in mentorship to engage and inspire students. These workshops also address the motivation and challenges faculty face when working with undergraduates, aiming to encourage faculty members to invest time and effort in mentoring undergraduates, and support them by providing resources to reduce the barriers for them to do so. The objectives for the two faculty workshops are as follows:

1. Help faculty to apply key elements of an entrepreneurial mindset (Curiosity, Connection, Creating Value) in the context of research,
2. Share stories of how faculty successfully attracted and mentored student researchers,
3. Identify successful strategies used by faculty to help students understand their EM through research engagements, and
4. Brainstorm methods to grow student curiosity, mental connections, and contributions to impactful work through intentional research mentorship.

The exact structure of each seminar was intended to be flexible so that individual institutions could tailor the content to be specific for their audiences. For example, facilitators at one university might point faculty towards research resources specific to their institution as a complement to the resources prepared as part of this project. Or, facilitators at another university might discuss how the resources could integrate into their research culture or be timed to align with other research activities for maximal impact. Or, facilitators at yet another university might tailor the discussion questions to appeal to and crowd-source from research-active faculty and graduate students, depending on the anticipated audience. Previous implementation of these workshops by our project team have employed all the modifications mentioned above to achieve the greatest impact across different university settings. Regarding workshop venues, we have integrated these workshops into existing departmental and college-level events, such as annual retreats and faculty meetings, as well as new events specifically designed for faculty development.

Workshop Surveys

We developed two surveys to evaluate the impact of the workshops on faculty engagement in undergraduate research experiences and their mentorship practices. The initial 17-item survey was conducted at baseline, as a benchmark prior to workshop participation, and the second 18-item survey was conducted after workshop participation. The surveys are linked by a unique identifier that allows the research team to evaluate changes in faculty practices and perceptions. We note that the benchmark survey was sent to all faculty in engineering departments at participating universities, while the follow-up survey was only sent to workshop attendees.

The first survey collected general demographic data from faculty, including career stage and degree of current engagement with undergraduate research. It also evaluated the extent to which faculty incorporate EM principles into their undergraduate mentoring practices, as well as faculty perceptions of student motivation for participating in research, concerns about mentoring undergraduate researchers, and views on the value and impact of undergraduate research. The follow-up survey revisited these ideas, and specifically assessed the impact of the workshop on faculty mentoring practices by asking about the usefulness of workshop materials and changes in mentorship style or perceptions of undergraduate research made as a result of the workshop material.

Data Collection
The initial benchmark survey was sent to 442 faculty across the five participating institutions (52 total respondents; 11% response rate). Workshops were then held at each of the institutions in relevant venues, including faculty research seminars, retreats, and professional development workshops. The follow-up surveys were sent to workshop participants from each institution one year after workshop completion (n = 21 total respondents).

Note that the baseline and follow-up surveys do not represent matched cohorts, and not all faculty who completed the baseline survey participated in the workshops. With that in mind, the comparison plots represent the practices and attitudes of faculty who participated in our workshops relative to faculty at large, but not a comparison of faculty practices before and after workshop participation.

Results and Discussion

For the benchmark survey distributed to a broad group of engineering faculty, a total of 52 responses were received. The baseline group of faculty were surveyed without attending the workshops and were evenly distributed between early career (0-6 years, 36%), mid career (6-15 years, 34%), and later career (15+ years, 30%). Over the past five years, this group of faculty collectively worked with 668 undergraduate students in research. Of these, 30% participated as volunteers, 27% were paid undergraduate assistants, and 43% enrolled through independent study, curriculum credits, or honors programs.

Overall, faculty members placed a high value on having undergraduates work in their labs, with an average rating of 4.3 out of 5.0 on this question. Over the past five years, 86% of these faculty members have had undergraduates participating in their work as co-authors in publications or presentations, and many of the students ended up continuing their research endeavors (e.g. went to graduate school or industry position focused on research) - only 14% of the all respondents said none in the past five years. It is interesting to note that faculty perspectives on how an undergraduate can be viewed as a successful researcher are quite diverse. The top three cited metrics are: 1) Understanding the objectives and motivation of the project, 2) The ability to identify a research question and/or formulate a hypothesis, and 3) Pursuing graduate study or a research-focused career.

When asked, “What motivates you to work with undergraduate students?” Faculty identified various reasons for engaging undergraduates in their labs (Figure 1). The green bars (1) indicate their top motivation, the blue bars (2) indicate their second motivation, and the yellow bars (3) show their third motivation. It can be seen in Figure 1 that the three most frequently mentioned top reasons were:

- Boosting research productivity
- Identifying promising candidates for graduate programs
- Assisting current graduate students with research

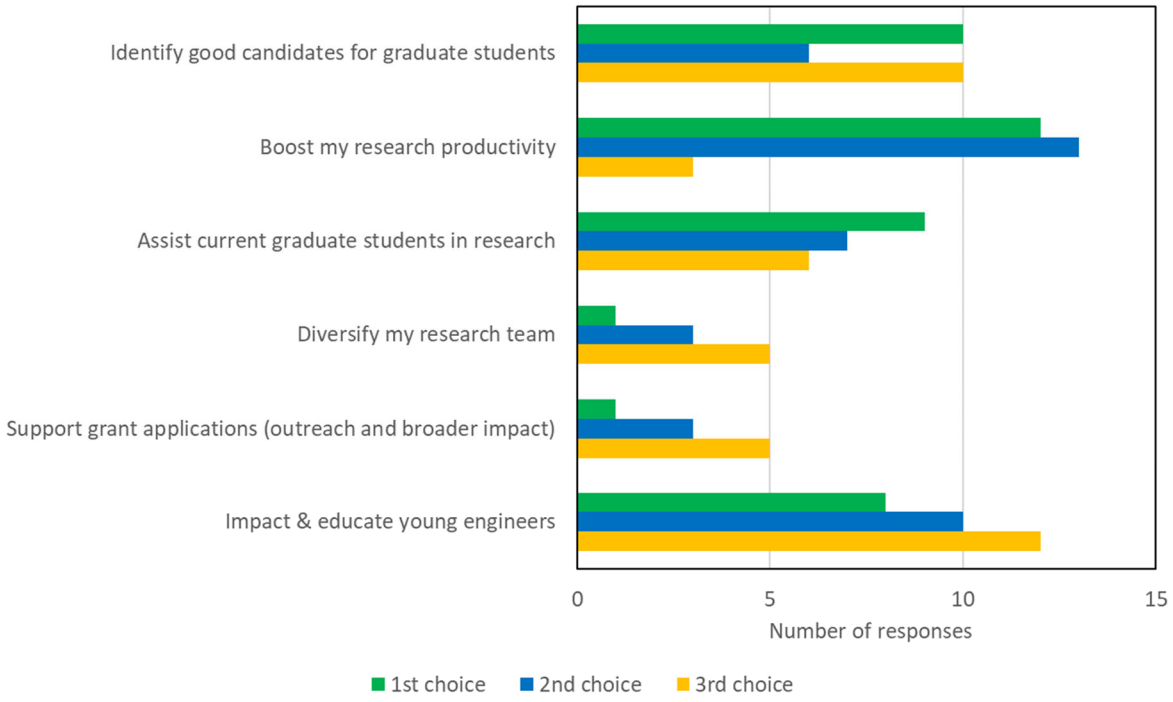

Figure 1. Faculty responses to "What motivates you to work with undergraduate students?"

A question was asked to identify the root causes of faculty reluctance to mentor undergraduates in research. As shown in Figure 2, the most commonly cited concern (selected by 45% of respondents) was the short duration of undergraduate involvement, which often prevents deep or prolonged engagement. Additionally, 17% of responses indicated the concern of "low rate of return". Other concerns included lack of research training, lack of student commitment (time and effort), and insufficient time to train/mentor them correctly.

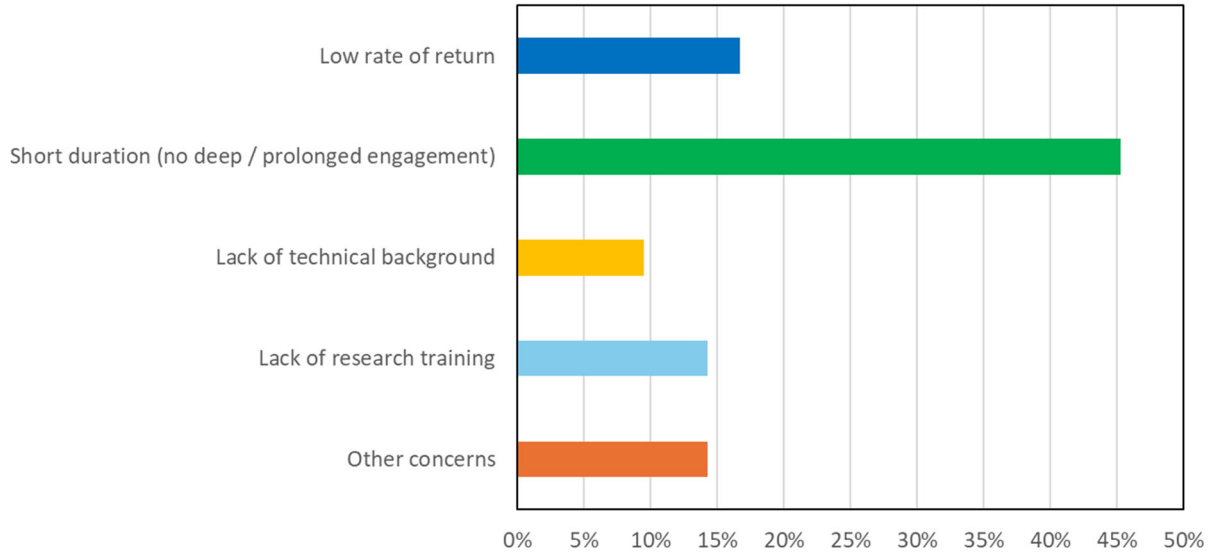

Figure 2. Faculty responses to the question "What is your biggest concern about working with undergraduate students?"

Faculty concerns about the short duration of undergraduate involvement were further supported by another question: “On average, how long does an undergraduate typically work in your lab?” Responses indicated that 38% of students worked for only a summer or a single semester, and only 17% stayed for more than one year. This often occurs because research opportunities rely heavily on individual faculty recruitment efforts and word-of-mouth, leaving many students unaware of the possibility of joining a research team until later in their undergraduate studies. The early exposure component of our project aims to address this issue [7].

The survey also asked faculty about their perceptions of students' motivations to participate in research. Responses to the question, “From your perspective, what motivates undergraduate students to engage in research?” are illustrated in Figure 3. The green bars (1) represent faculty views of students’ top motivation, the blue bars (2) show their second-highest motivation, and the yellow bars (3) indicate their third-highest motivation. According to Figure 3, the top three motivations (from the faculty’s perspective) are:

- gaining hands-on research experience
- exploring their interest in science/engineering
- enhancing their resume.

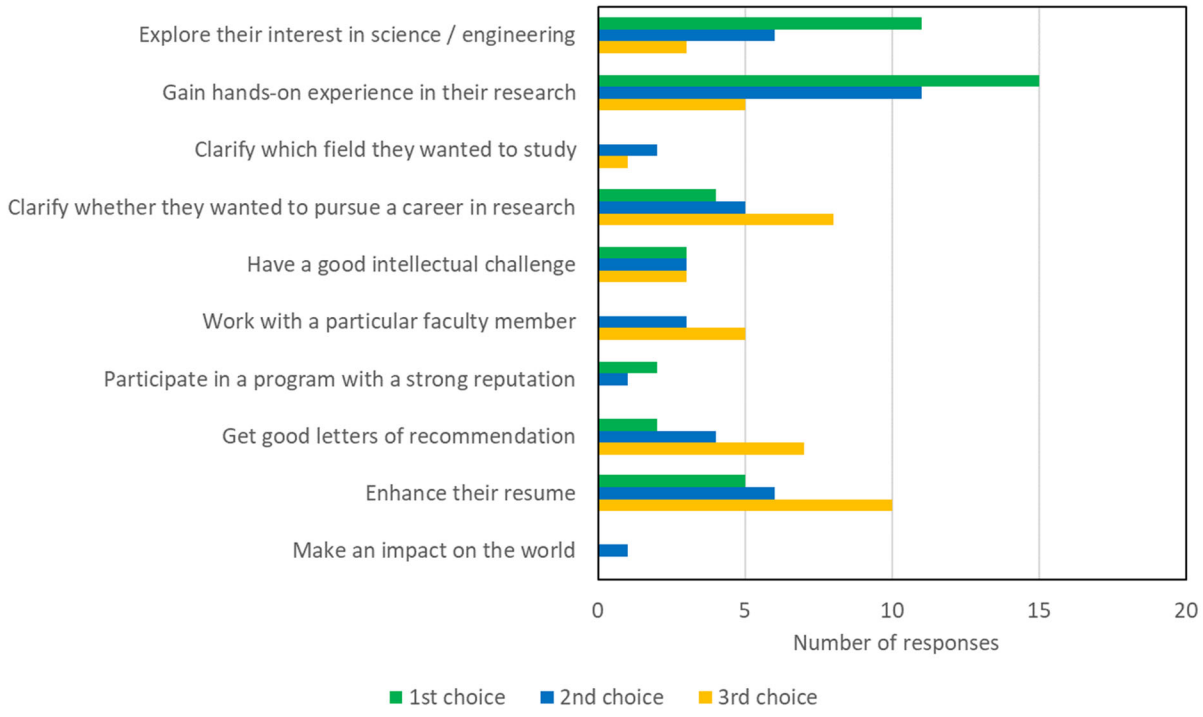

Figure 3. Faculty responses to the question “From your perspective, what motivates undergraduate students to participate in research?”

When asked, “On average, how many hours per week do you spend mentoring each undergraduate student in research?”, faculty responses are shown in Figure 4. Approximately 15% reported spending less than 30 minutes per student, 34% spent 30 minutes to one hour, and the largest group (38%) spent one to two hours per week. Meanwhile, 13% of respondents indicated spending more than two hours per week mentoring each undergraduate researcher.

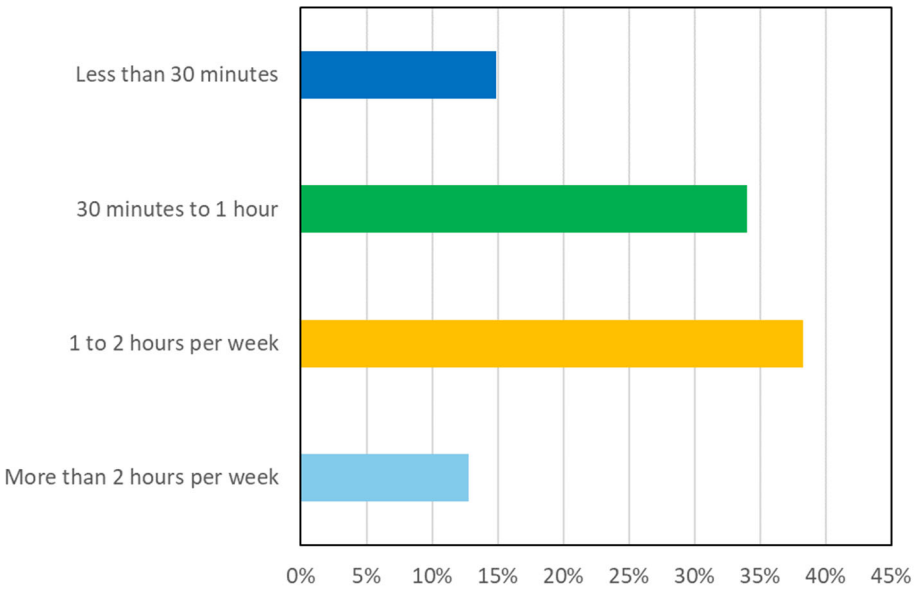

Figure 4. Faculty responses to the question: "On average, how many hours per week do you spend mentoring each undergraduate student in research?"

When asked about their efforts in mentoring undergraduate researchers' entrepreneurial mindset, faculty responses are summarized in Table 1. Overall, faculty members believe they make an effort to foster curiosity among their undergraduate researchers on a regular basis (average rating of 4.2 out of 5.0). On the other hand, most faculty members do not typically guide students to consider how a discovery might be scaled or sustained, including aspects such as revenue streams, key partners, costs, and key resources (average rating of 2.9 out of 5.0).

Table 1. Faculty Self-Evaluation of Mindset Mentoring for Student Researchers

Statement	**Degree of Agreement** *1. Strongly Disagree; 5. Strongly Agree*
On a regular basis, I make an effort to foster curiosity among my undergraduate researchers.	4.2
On a regular basis, I ask my undergraduate researchers to explain the impact (societal, economic, intellectual, etc.) of their research projects in presentations or reports.	3.4
On a regular basis, I ask my undergraduate researchers to understand a problem in terms of how a discovery could be scaled and/or sustained (such as thoughts of revenue streams, key partners, costs, and key resources).	2.9
On a regular basis, I ask my undergraduate researchers to describe the needs and motivations of various stakeholders of their projects, such as industry sponsors, other research groups using the results, or eventual end users of the technology.	3.3
I provide guidance to my graduate students and post-docs on how to mentor undergrads.	3.3

While the faculty group that completed the surveys after the workshops was smaller and are not completely matched to those in the baseline group, some interesting observations can still be made about the post-workshop results (Figures 5 and 6). Faculty who attended our workshops are more likely to see value in working with undergrads. However, this result may represent a previously held opinion, which motivated them to attend the workshop. Faculty who attended our workshop may be more likely to ask undergrads to explain the impact or context of their research. Several faculty still disagreed with the statement that they make an effort to foster curiosity, that they ask their students to describe the needs of various stakeholders, and that they ask their students how a discovery could be scaled following the workshops. Follow-up conversations with faculty that continue to hold those perspectives following the workshops will likely result in areas that can be improved in our current workshop content.

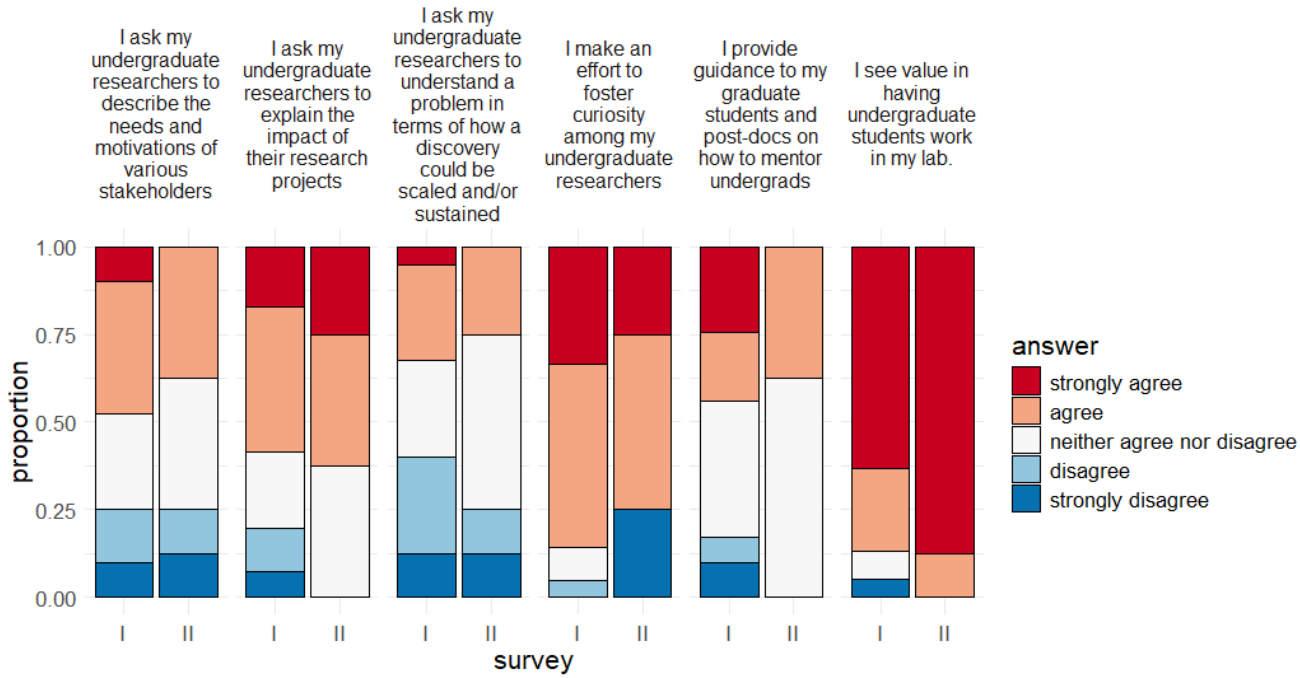

Figure 5: Faculty responses to multiple statements about their mentorship of undergraduate research students. The proportion of faculty who agree (red or orange) or disagree (blue and light blue) are indicated for the baseline group (I) and the post-workshop group (II).

Faculty who attended our workshops generally saw the same motivations among their undergraduate researchers as the baseline faculty, with major motivations for undergraduates being gaining hands-on experience, clarifying career goals, and building their resume. Interestingly, the responses of intellectual challenge, participation in a program with a strong reputation, and work with a particular faculty member did not receive any votes in the workshop group.

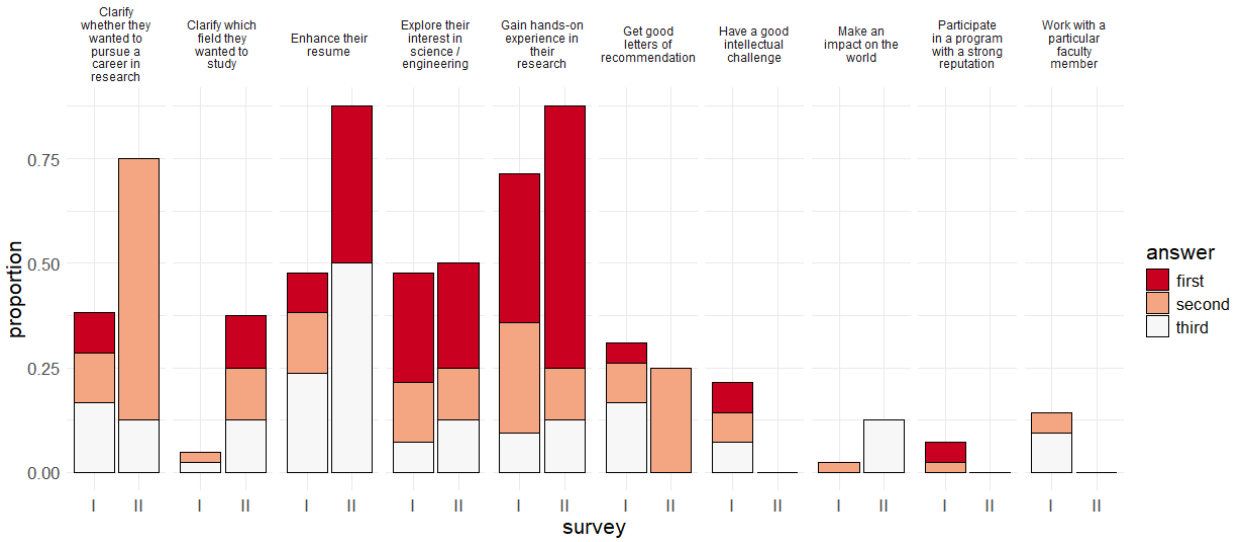

Figure 6: Answers to the question "From your perspective, what motivates undergraduate students to participate in research?". Faculty were asked to rank their top three responses. The compiled results for each possible motivation are indicated in the figure above for the baseline group (I) and the group that attended the workshops (II).

In their reports, several faculty members described leveraging the concepts of curiosity, seeing connection, and value creation in their mentorship to enhance research productivity among undergraduates. Example actions included:

- Implementing a research contract or memorandum of understanding at the beginning of a project, including the value proposition of the research for both students' professional development and the mentor's research program;
- Identifying new venues for students to disseminate their research, including course-based research;
- Initiating discussions about the project's value for consumers or stakeholders;
- Creating regular team presentations among graduate/undergraduate students, featuring group research presentations with peer feedback and idea sharing;
- Facilitating research presentations by external presenters that connect to real-world applications.

Several faculty members reported noticeable improvements in the research progress by their undergraduates following these interventions. Students have become more aware of the practical implications of their work and are attempting to address real-world problems using the results/methods of their studies. The creation of a friendly and supportive research environment through group presentations has fostered creativity. Some faculty also reported improved student self-confidence through these interactions.

Conclusions and Future Work

Overall, we find that faculty participating in our benchmark survey are receptive to mentoring undergraduate researchers and that many of them have already served as mentors. At baseline, they rank research productivity, for the lab overall as well as for graduate students in the lab, as

two of the top motivators for including undergraduates. The third top motivator was identifying promising candidates for graduate programs. This suggests that faculty buy-in could continue to be improved by emphasizing the positive impacts of undergraduate research on individual labs.

Although the majority of our respondents have mentored undergraduates and agree that it is a positive practice, undergraduate mentorship is not without challenges. The most common concerns among our faculty respondents was the short duration of undergraduate involvement and a "low rate of return." This is directly tied to the failure to achieve the top faculty motivators that are centered around increasing productivity. Here, we believe that the resources and discussions facilitated by our faculty development workshops can speak to these concerns by providing faculty with supportive communities in which to troubleshoot specific issues, share resources, and build stronger mentoring practices.

Our current project is designed to collect longitudinal data on the faculty workshop participants; however, our initial follow-up survey had a lower response rate and may represent a biased subsample of the faculty population compared to the benchmark survey, making it difficult to draw specific conclusions. Efforts will be made to increase the number of post-workshop responses and to match the responses from faculty who completed the survey before and after the workshops. From the responses we received, we observed that faculty who participated in our workshops were more likely to "strongly agree" that they saw value in having undergraduate researchers in the lab. We observed that they were also more likely to ask undergrads to explain the impact or context of their research, which is a practice that may help to increase student engagement in the research experience. Future workshops and ongoing data collection will increase the number of responses and improve our ability to understand the impact of the workshops on undergraduate research mentoring. Due to the intentionally flexible nature of our approach, these workshops can be implemented at additional institutions, further increasing the generalizability of our conclusions.

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