The "Muddiest Point" in Undergraduate Research: A Survey on Students and Faculty about Existing Challenges

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***Abstract*—This work-in-progress (WIP) research paper presents a plan and discusses some preliminary efforts to study the existing challenges of STEM undergraduate research (UR) from both faculty mentors' and students' perspectives. The benefits for undergraduate students to conduct research activities are well recognized by engineering educators. However, challenges to engage more novice researchers and to create values still exist, especially in primarily undergraduate institutes (PUI) where research resources may be limited. Other possible difficulties include misconception of research, time commitment, disengagement with mentors and lack of technical preparation.**

The goal of this project is to further investigate and identify these issues by a direct interaction with participants at multiple PUIs. Through one-on-one interviews, we will hear the voices from student participants regarding their experience in UR, such as common misunderstandings, motivation, typical learning curves and impact on the careers. For faculty mentors, the focus is their reflections on the recruitment process and mentoring experiences. Using snowball recruitment that starts from the authors' own institution, we will reach out to participants at other PUIs based on our professional contacts, as well as local and national research conferences (e.g., Undergraduate Research Symposium and National Conference on Undergraduate Research). The firsthand information will ultimately help us address these potential challenges by developing a more personalized training program that aims to enhance students' preparedness and performance in research. We also envision the project itself will facilitate more productive conversations between faculty mentors and students.

Keywords—Undergraduate Research, Primarily Undergraduate Institutes, Challenges, Interviews

I. INTRODUCTION

Undergraduate research has been recognized as an essential element by most STEM educators. Besides the popular and competitive Research Experience for Undergraduates (REU) programs supported by National Science Foundation (NSF), many STEM programs also build research element into curriculum design and encourage faculty to engage students as early as sophomore and freshmen years [1] to maximize their exposure to research methods and critical thinking. In typical research projects facilitated by the project-based learning pedagogy, students are experiencing open-ended problem-solving process which can enhance students' technical skills, team collaboration and technical communication [2]. Other benefits of doing research in college are also well studied. One of the most cited assessment works was done by SRI International [3], which surveyed 15,000 participants from 2003 to 2005. The report indicated positive outcomes such as growing interests in STEM career/graduate school, a boost in confidence and improvement of retention rate. At the same time, a standardized survey known as "Survey of Undergraduate research Experiences" (SURE) [4, 5] was developed and quickly being adopted by many REU sites. The follow-up studies [6, 7] with SURE also echoed similar benefits stated above.

From the faculty's perspective, engaging undergraduate students in research activities can also benefit their own research and teaching agenda. Many faculties would identify and encourage interested students to continue research projects in graduate school. Some programs [1, 8, 9] built research projects in coursework to promote active and project-based learning in classrooms. One study done by University of New Hampshire [10] also revealed that a positive mentor-mentee relation could improve faculty's satisfaction in their daily jobs.

Despite these impactful benefits, several studies also discussed the challenges to engage and mentor undergraduate researchers. Typical challenges reported by faculty would include the availibity of resources (e.g., funding, time, hardware/software technologies), perceptions as well as supporting culture environment [11-13]. In a primarily undergraduate institute (PUI) where resources are typically limited, this challenge could be more prominent. Many of the benefits mentioned above will become meaningless if faculty are reluctant or unable to engage students in a research project.

In this WIP paper, we are presenting our research agenda to investigate the challenges in undergraduate research (UR) that are less reported by literature but may be genuinely faced by faculty from PUIs. Built on the existing literature, we designed our survey questions and will conduct multiple interviews on both faculty and students starting from our own institute.

II. LITERATURE REVIEW

A. Keys to a successful UR experience

Although STEM research projects may come in a variety of formats, such as laboratory experiment, field study, theory development, modeling, design and even entrepreneurial work, a successful UR project relies on a few key common factors. From faculty's point view, developing healthy and productive mentorship is essential for a student's success. "Mentoring is sharing the excitement of discovery", as Vandermaas-Peeler et al. [14] pointed out. Occasionally, it could be misunderstood as extended teaching outside the classroom or simply one-on-one tutoring time, but an effective mentorship could reach far beyond teaching only technical knowledge. Shanahan et al. [15] named "ten salient practices" for UR mentors in their recent literature study work. To name a few:

- Strategic pre-planning
- Clear and rigorous expectation balanced with emotional support
- Community building with the entire research group
- Dedicate time to one-on-one mentorship
- Encourage student to take ownership of the project
- Provide professional development opportunities such as seminars and conferences for students to present and network

These best practices can be divided into three major categories: technical preparation, professional development, and mental/emotional support. To begin with, a productive UR project should consider the level of knowledge of students and make connections to their coursework. Student-led seminars [16], peer studying groups and graduate student mentorship [17] are general strategies to facilitate technical learning. Second, it is recommended that a "scaffolded research structure", namely, a gradual transition from strong mentorship to self-autonomy, could benefit students with different learning styles. The development of "ownership" is crucial for students to enhance their self-directed learning skills [6]. When students genuinely believe the research is relevant for their future careers, they become more intrinsically motivated [18] and are more willing to explore the unknowns. To promote stronger ownership, faculty mentors need to trust students work, help them embrace the failure and treat them as junior colleagues.

Regarding mental/emotional support, most mentors would agree that it is crucial to be available, attentive to listen, and open to discussion especially when there is disagreement [19]. In addition, a more personalized mentorship and strong student-faculty tie can also help enhance their identity in STEM fields, especially among underrepresented minority groups [20].

Most of the research works mentioned above are from useful guidance for faculty and program improvement. Although there are two parties in UR: students and faculty, there are less pedagogy research focusing on student's perspectives. In the Survey of Undergraduate Research Experiences (SURE) [4], specific questions are designed to measure student's gains with in technical and professional skill development. The survey was completed by more than 1000 students across 41 institutes. Based on the Likert scale from 1 to 5, students reported great learning gains in categories such as "laboratory techniques", "research process" and "tolerance for obstacles" [4, 5]. In addition to assessment of summer research experience, Burgoyne et al. [21] evaluated general research awareness among 317 undergraduate medical students using a similar questionnaire. Their research called for an integration of research skills into curriculum, since most students who were positive in pursuing research were not aware of faculty's research activities at their own school. Standardized survey approach, despite its broader scope and coverage on large group of students, has limitation to assess individual opinions. Falconer et al. [22] applied phenomenological approach to study 17 students' professional growth during a summer research program. The research presented a longitudinal evolution of students' perceptions on UR, namely excitement, doubt, value identification and persistence. It also indicated a strong social network (e.g. peer support and graduate mentorship) would help combat against negative feelings through the project work, which has been confirmed by another study done by Faurot el al. [23] in 2013.

Given the essential role of peer learning, it may be surprising to see limited published works that promoted student-to-student knowledge transfer. In other words, what would students suggest to their peers in terms of best practices in a UR project? Student's voice matters. In one article published by Nature at the Career Column [24] in 2019, Mr. Wang, an undergraduate student participating a UR project, shared his experience and provided a few suggestions to his peers:

- Contact potential mentors with confidence
- Understand the importance of reading literature and start to think as a scientist
- Set goals for yourself and let your mentors know
- Develop a health balance between research and coursework
- Be resilient and learn to cope with failure and pressure

The list is not comprehensive to cover all the aspects of research, but it is a reflection on "I wish I had known…" type of statement. Successful UR experience requires mentor's or program director's efforts running the project. It is also about facilitating such student-to-student knowledge transfer that could prepare them before joining the research group.

B. Challenges of UR at PUIs

In contrast to the vast amount of literature and surveys designed to evaluate the UR benefits, the research work assessing UR challenges, especially in a PUI environment, is inadequate. Defined as institutions that offer less than 20 doctoral degrees [25], PUIs are serving more than 65% of undergraduate students in the US according to report in 2013 [26]. Even though PUIs are positioned in the frontline of postsecondary education, assessment of the challenges in UR is not well done. Due to limited resources, institutional structure or perceptions, faculty at PUIs may have more obstacles and even feel reluctant to engage undergraduate students in their research.

In a pedagogical research conducted by Eagan et al. [12], more than 4800 STEM faculty nationwide were surveyed regarding their willingness and ability to mentor undergraduate researchers. A majority of faculty reported time was their primary concern, since the schedule could be quickly filled up with teaching, research and service and 50 working hours/week is not uncommon [27]. In many PUIs where teaching 9 to 12 credits of class each semester is expected, less than 50% of faculty who actively included undergrads in their research, could commit time on weekly small group or one-on-one mentoring activities [28]. In addition, perceptions about undergraduate students created barriers. "Students are underprepared" and "Students have little commitment" are top reasons [29, 30] why faculty are struggling in supervising undergrads, while maintaining their productivity in research. At some PUIs, in absence of master's students, some faculty may prefer collaborations with other colleagues as well. Funding was identified as another issue. Even though organizations, such as NSF and Council of Undergraduate Research (CUR) [26], have offered PUI faculty numerous grant opportunities, some are either not familiar or simply think their projects are not eligible. Finally, institutional support and culture play an important role in involving undergraduates in research [12, 13]. Faculty who believes his/her research work is valued by colleagues and administrators are more likely to invite undergrads into the research lab.

In summary, faculty in PUIs may face challenges due to their limited time of research, institutional structure, perception as well as lack of infrastructure. There are, nonetheless, far less research effort to reflect student's perspectives on their challenges, especially at PUIs. In this research proposal, we bridge this gap by hearing their voices and concerns, with a potential to develop a more effective training program that better prepares faculty and students to embrace research opportunities.

III. METHOD

The current gap identified from the literature motivated us to assess challenges of UR at PUIs. Aiming to develop a training program that better prepares students in research activities, we designed two major research questions: (a) Do the students think if they have received adequate support? and (b) What challenges do faculty currently have to engage and mentor undergrads and what are their actions to become productive in UR?

TABLE I. KEY QUESTIONS ASKED DURING THE STUDENT INTERVIEWS

Assessment	Interview Questions
Motivation (s1)	What made you interested in this research topic and where did you hear about this opportunity?
Preparation (s2a)	What technical courses did you take before joining the research?
Preparation (s2b)	What training or preparation did you receive at the beginning?
Experience (s3a)	What challenges did you have through your research experience and how did you overcome those challenges?
Experience (s3b)	How did you balance your research with coursework?
Experience (s3c)	How did your mentor support you through the research?
Reflection (s4a)	What advice would you give to your peers who would like to participate in research?
Reflection (s4b)	What is your next step in your research/study?

TABLE II. KEY QUESTIONS ASKED DURING THE FACULTY INTERVIEWS

Assessment	Interview Questions
Motivation (f1)	What motivated you to include undergraduate student in your research project?
Preparation (f2a)	How did you recruit undergrads in your research team?
Preparation (f2b)	What training or preparation did you offer at the beginning?
Experience (f3a)	What challenges did you have when working with undergraduate researchers and how did you overcome them?
Experience (f3b)	How did you balance your research with teaching load?
Experience (f3c)	How did you support the students in your research group?
Reflection (f4a)	What advice would you give to your colleagues to better mentoring student?
Reflection (f4b)	How do you envision the UR in your department or college?

These big questions will be answered through a series of live interviews over phone calls or ZOOM. As a pilot study, we will perform around approximately 30 one-on-one semi-structured interviews with student researchers and faculty mentors to gather preliminary data from our own institute, which offers 130 undergraduate programs, 80 master's programs and 5 doctoral programs. Among the 12000 currently enrolled undergraduate students, about 27.4% self-identify themselves as African American, Hispanic, Native American, Asian and Pacific Islanders. The student to faculty ratio is 22:1 in Fall 2018. Although it is currently not a focus, we plan to study the demographic information of UR in our own institute as well. We recognized that conducting individual interviews may limit the number of participants compared to a standardized survey sent online, but the benefit is to genuinely hear their voices and develop better understanding among the UR community.

To translate the research questions into interview questions, we took references to two well developed surveys, namely SURE [4] and URSSA [31]. The questions listed in Table I and II assess four major aspects through a UR process: Motivation, Preparation, Experience and Reflection. At first, we often would also let the participants to introduce his/her work as well as their department culture in UR. Since the interviews are intended to be conversational, follow-up questions are allowed, and the lists above are only the key questions during the 20-min interview. This pilot study is expected to have a small sample and only qualitative analysis will be considered.

This research project has been reviewed and approved by the Institutional Review Boards (IRB) to protect the participants' rights and privacy. Through the interviews, no identifiable information is gathered or recorded. The participants are recruited via their contact emails from their published works, such as posters, conference proceedings and presentations. Upon consent, participants grant us permission to include their direct quotes in the current and future publication. The faculty and students may or may not come from the same project team, but their participation information is confidential to each other. Therefore, the opinions they shared are independent.

IV. PRELIMINARY RESULTS

At the time of drafting this paper, six students and four faculty mentors have responded to the interview inquiries. This section will briefly discuss our preliminary findings so far.

Motivation. All six students reported they were initially motivated by the applications of the research topics, which they learned from their courses. Four students regarded their research experience as an essential leverage to graduate school and two students motivated themselves through personal relations with the research. For example, one student who did two summer projects in vehicle control systems, said: "My father is a mechanic and I have been amazed by the automobile control system since childhood." The other, who is a freshman, said that she just loved to try new things in college, including a challenging research project. On the faculty side, their hesitation on the recruitment is noted. One junior faculty said he was unsure what potential a student would possess, because his discipline requires a high-level computation, and their familiarity of advanced math skills is usually lacking. On the positive side, one faculty mentor shared that he was motivated by a student's proposal and guided the student to develop his own project. The encouragement from the department administrators and senior faculty also motivated junior faculty to recruit students. In other words, a positive department culture increases the probability of UR, as Eagan et al. [12] indicated.

Preparation. Diverse responses are gathered from questions s2b and f2b regarding preparation for the research project, ranging from "no preparation at all" to "two weeks of hands-on guided training". Hands-on training is appreciated and jargons in literature are always challenges, reported by the students. Owing to the interruption of Covid-19, students received less physical lab training and relied more on virtual training, such as videos recorded by faculty and online tutorials. Faculty seemed to be a "debate" over the effectiveness of literature as well, but all participants agreed that students need time for one-on-one discussions to resolve their questions on time.

Experience. Most challenges mentioned by the students and faculty (questions s3a and f3a) agree accordingly. Time is indeed a primary concern. While summer is often considered the best time to work on research, five students mentioned that they must occasionally work over the weekends through the semesters (so do the faculty). Students pointed out that time management was a skill and they wished they had known some strategies to maximize the working efficiency. Besides time, the next challenge is lack of communication. In other words, students receiving little timely guidance when they got lost felt less supported by their mentors. One student particularly revealed that he once considered to give up, but eventually received assistance from his peers. One common practice to support students is to set up appropriate learning goals. Students appreciated that their mentors could help break down the work into small goals and keep them in check along the semester. "Identifying the 'correct' students to do research" is viewed as the second challenge for the faculty. It is not just an issue of student's interest or technical preparation. A follow-up question shows that the true headache is shortage of commitment. When a well-trained student quits for an industry internship opportunity that pays more than the summer research assistantship, the "high turnover rate" could significantly slow down the progress. In some areas of high-tech research, such as semiconductor, machine learning and nanoscience, training could easily take up to one semester and student's interest may quickly fade. "Research is not for everyone, so I won't mind if some students leave the group after a few weeks of trial. At least the student knows where his/her passion is," one open-minded mentor said. At last, faulty discussed difficulties in developing an effective research agenda that was both academically rigorous and flexible to accommodate different learning styles, similarly reported by the literature [15]. All the faculty participants were satisfied with the current internal funding opportunities and stipend support but recommended a less complicated administrative process when purchasing equipment and software.

Reflection. Students and faculty were asked to summarize their best practices and plans for the next step. "Be ready to take on challenges and failure" is frequently emphasized by the students. Being open-minded and confident was recognized as a key to success. "I see research as a way to explore. I know my work may be evaluated by my publications, but learning so many new things was already cool," one student reflected. As the next step, dissemination and preparing for graduate schools are top responses from the students and they greatly valued their graduate student mentors for the information. The faculty stressed the importance to integrate research content into coursework, so that students may get interested in the topic as early as possible. For junior faculty, a "good reputation" could mean a lot beyond the classroom teaching. One faculty mentor noticed that students would prefer to do research with faculty who have passion in teaching, although there is not clear supporting evidence from the student interviews so far.

V. Limitations and Future Work

There are several limitations on current work. The research focuses more on STEM UR rather than the general UR. It is also worth noting that, even within the STEM fields, UR opportunities are not created equal. There are more biological and life sciences UR activities than engineering and computer science disciplines. About 80% of the undergraduate posters presented within our school are related to biological and life sciences, in which the lab settings usually facilitate engagement in high level of UR productivity. This phenomenon was noticed and reflected by a few previous studies [12, 32] as well. As we mentioned, the current study covers only 30 interviews and there may be biases due to institution culture and our personal affiliations with the interviewees.

For the future work, we will first organize these quote fragments into three categories (a) professional (b) technical and (c) mental, upon completion of these interviews. A modification of interview questions is considered. For example, one senior faculty recommended us to include questions related to Covid-19 impact on UR, since his discipline that requires field work and out-of-state travel is severely impacted. We will assess the common practices to support students. Second, with a better view on a variety challenges faced, we plan to reach out to students and faculty in a few other PUIs to continually collect data. Third, internally, we will organize multiple informal seminars and conversations within the UR community to facilitate student-mentor communications as well as sharing of learning experiences among peers. Finally, as a long-term goal, a training program that offers basic preparation for undergraduate researchers can be developed and possibly shared with other PUIs.

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