AMERICAN SOCIETY FOR MICROBIOLOGY | JMBE Journal of Microbiology & Biology Education

Perspective

Challenges for activating undergraduate research: a summary from the 2021 American Society for Microbiology Conference for Undergraduate Educators

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ABSTRACT Based on a growing understanding of the many benefits of undergraduate research, advocacy for undergraduate research experiences has increased, with an emphasis on implementing course-based undergraduate research experiences (CUREs). To understand existing efforts to promote undergraduate research as well as challenges to implementation on higher education campuses, we hosted a session about undergraduate research at the 2021 American Society for Microbiology Conference for Undergraduate Educators. Session participants were surveyed about their experiences with undergraduate research on their home campuses, and we then conducted additional research on the undergraduate research offerings at the participants' home institutions. Survey responses and the discussion group identified many challenges to impactful undergraduate research facilitation. Several overarching themes emerged across survey responses and breakout room discourse, including funding, mentor recruitment, early skill development, diversity, equity, and inclusion (DEI) and identifying and connecting with students. In this perspective, we elaborate on this discourse to inspire and assist those seeking to foster undergraduate research in the field of microbiology and beyond.

KEYWORDS experiential learning, undergraduate research, undergraduate research experience (URE), course-based undergraduate research experience (CURE)

Promoting undergraduate research experiences (UREs) for students continues to be a major focus of science education, and more specifically biology education initiatives. The benefits of participating in UREs are abundant and well-documented, including an overall increase in grade point average (1), an increase in skills such as poster presentation and other scientific public speaking (2), and an increase in retention and persistence of science, technology, engineering, and mathematics (STEM) majors (3), particularly those from underrepresented groups (4). Students engaged in UREs report enhanced scientific identity, a greater sense of belonging in the scientific community, increased interest in pursuing science-related degrees, and a heightened commitment to a science career, along with the development of valuable "soft skills" like critical thinking and effective communication (5, 6). Furthermore, these gains have been documented for underrepresented minority groups of students (4, 7, 8), further advocating for the implementation of undergraduate research experiences. Although the benefits of UREs are numerous, the implementation and facilitation of UREs do not come without challenges.

UREs represent a broad category of experiences that undergraduates can engage in. To frame our current study and discussion, we consider two groups of UREs: traditional (e.g., external internships and experiences in on-campus labs) versus course-based undergraduate research (CUREs (9)). Traditional research experiences vary in size and

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The authors declare no conflict of interest.

Received 13 July 2024
Accepted 29 December 2024
Published 14 February 2025

scope, with faculty interested in fostering them facing barriers such as lack of institutional support, resources (e.g., time, space, personnel, and funding), and faculty incentives (10). CUREs differ from traditional laboratory research settings by integrating student research experiences into a curriculum, helping overcome many of these barriers (11). As a result, CUREs have been posited as the gold standard as they can more equitably serve underrepresented minority students and reach students early in their college careers, thus enabling them with the skills to enter a research laboratory earlier (12). Furthermore, CUREs can reach more students than traditional UREs, which usually involve one mentor and one or a small team of undergraduate researchers. Regardless of whether the URE is traditional or a CURE, faculty still face challenges with the implementation of these experiences.

Previous perspectives have explored ways to overcome the unique barriers of UREs (13). We, therefore, do not attempt to comprehensively review ways to overcome barriers to UREs in our current perspective. Instead, here we present notes and observations from a virtual workshop on diverse undergraduate research initiatives at the 2021 American Society for Microbiology Conference for Undergraduate Educators (ASMCUE). We believe this discourse will add to the growing discussion of UREs. This will be useful for those seeking to foster undergraduate research in the field of microbiology and more broadly to STEM. Our discussion of common barriers and methods that have been used to overcome them should benefit researchers and instructors across all fields.

Methods

Three of the authors (G.O., M.A.B., and A.C.S.) virtually attended the 2021 ASMCUE and hosted a 30-minute breakout session to explore effective components of existing undergraduate research initiatives and the biggest challenges or barriers to facilitating undergraduate research. Participants represented a gradient of campus sizes and types (see Results). Participants were offered a survey (Supplementary Material 1) during the session and made aware that breakout room discourse and survey responses would be used in a publication as part of an assessment of undergraduate research infrastructure. The authors then analyzed the recorded conversations from the breakout rooms using an inductive qualitative approach. From this analysis, several codes and themes emerged: characteristics of effective undergraduate research, barriers to undergraduate research, and helpful prerequisites and support for undergraduate research. Coding reliability was captured through consensus coding in which the research team would individually code the data and discuss any discrepancies until a consensus was reached. In addition to the survey and breakout room data collection, we also searched through the participants' college and university undergraduate research websites (hereafter, "program websites") to further document the nature of the attendees' research initiatives, including its funding source, student compensation (if any), mentor-identification approach, early-skill development initiatives, diversity equity and inclusion (DEI) efforts, and recruitment strategies.

Program websites

While searching through program websites of workshop participants, we oriented ourselves as students interested in participating in undergraduate research. We used Google to search for "University Name" + "Undergraduate Research," and we navigated through each university's website in search of UREs. Table 1 displays the variables collected from each website and information recorded, and Table 2 shows the outcomes from this search. Only information accessed was included in the review of specific program websites, even though the participant's institutions may host other initiatives either not found by the team or undocumented online. Thus, we preemptively note that any oversights of existing programs in our review could provide evidence that poor communication and lack of transparency may represent barriers to the successful implementation of undergraduate research (see *Results*).

TABLE 1 Variable descriptions for program website analysis

Variable	Instructions
Institution name	Record name of institution
Type	Record whether university is • Public • Private
Funding source	Record source
Student compensation	Yes/No
Lab placement	Yes/No
Discipline	Record (STEM, Microbiology, etc.)
Lab skill transfer	Yes/No

Results

The participants came from thirteen institutions in the United States. Six institutions had undergraduate student populations between 18,000 and 33,000, while the remaining seven had undergraduate populations between 900 students and 5,600 students. Eight of the thirteen (62%) institutions award PhDs, four institutions award master's degrees as the highest degree, and one awards associates degrees as the highest degree. Seven institutions were classified as public institutions, while six institutions were classified as private institutions (Table 2). Notably, these groupings do not align with the student body sizes listed above; that is, the schools with the smaller populations were not necessarily public institutions. Undergraduate research websites were not found on two of the thirteen websites, and the remaining eleven ranged in scope from formal, institution-wide programs to smaller efforts housed in departments or under individual faculty.

Survey responses and breakout session discourse identified a wide array of challenges to impactful undergraduate research facilitation as well as a variety of approaches for overcoming such challenges (Fig. 1). Several overarching themes emerged across survey responses and breakout room discourse including funding, willing mentors, early skill development, efforts in diversity, equity, and inclusion (DEI), and identifying and connecting with students. We summarize major points by these themes in the following sections, which are presented in order of importance based on the frequency of mention. Analysis of the program websites revealed for undergraduates, how research experiences are implemented, funded, and skills are developed.

Funding

Access to funding has been previously recognized as a prevalent barrier to undergraduate research (14), and this trend continued across our survey responses and breakout room discussions. Funding was mentioned not only in the context of funding research generally (e.g., lab equipment and supplies) but also in the ability to pay student

TABLE 2 Participants (13) represented a gradient of campus sizes, institution types, and the highest degree awarded by the institutions

Demographic		Percentage	Count
Size	<10,000 students	53.8%	7
	>10,000 students	46.2%	6
	Total		13
Institution type	Public university	53.8%	7
	Private university	46.2%	6
	Total		13
Highest degree awarded	Associate's	7.7%	1
	Master's	30.8%	4
	PhD	61.5%	8
	Total		13

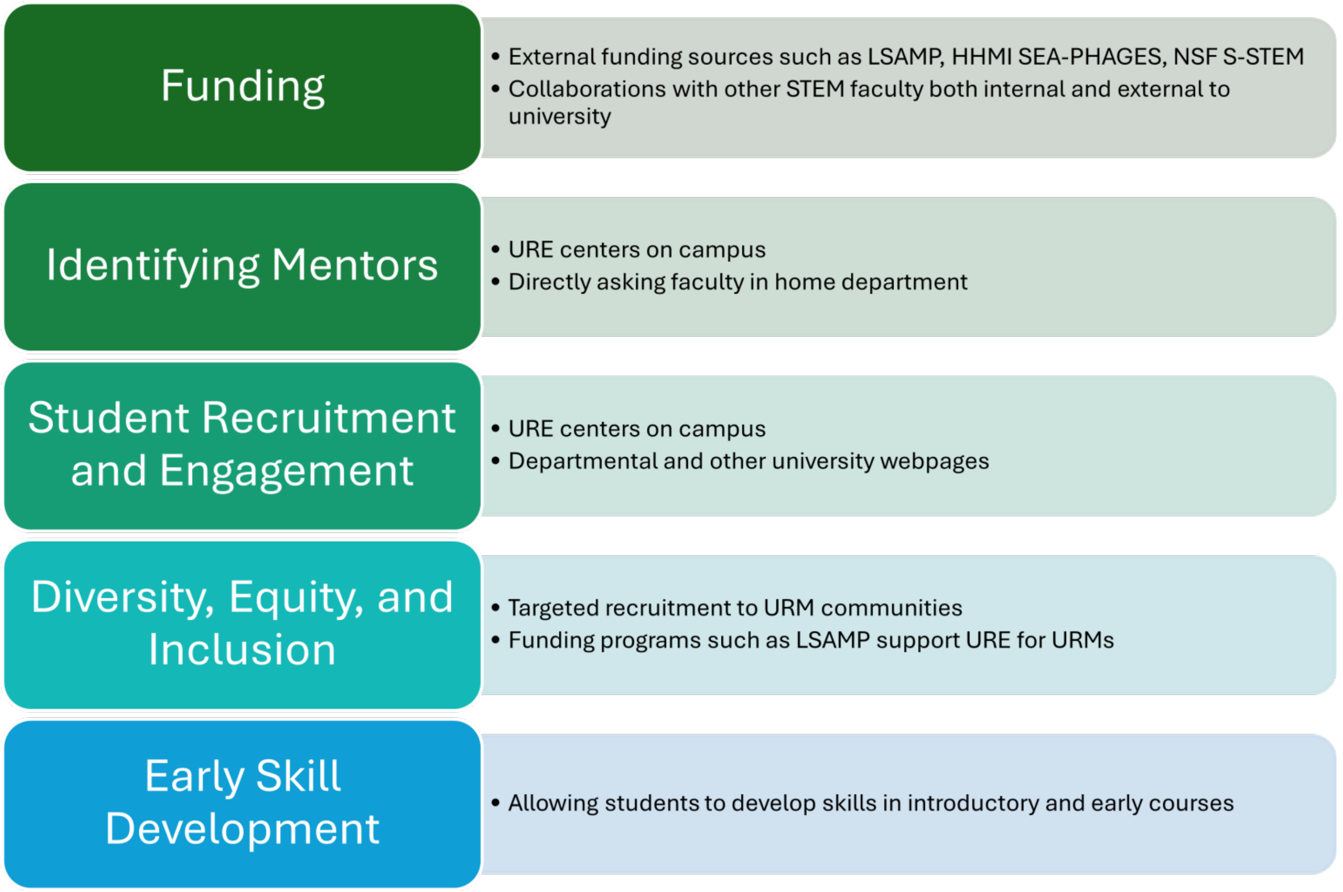

FIG 1 Challenges to UREs and proposed solutions to overcome these challenges.

researchers. Paying students specifically emerged as a focus within concerns about funding. Undergraduate students, and particularly those in underrepresented communities, often cannot afford to conduct time-consuming research for free when balancing part-time jobs or other obligations (15). Moreover, less than half of the sample advertised paid research positions, suggesting a need for more funding for UREs. Many of the participants mentioned the difficulties students have participating in unpaid UREs when balancing school and part-time jobs. One participant wrote, "Since I teach on a community college campus, funding is an issue." Another participant wrote, "Some years there is $ [sic] and a committee to distribute funds, but not always." Another participant discussed internal funding, saying "Professors have a small stipend for materials, but the requirements for faculty research is [sic] vague to say the least. There is little incentive to build a strong program." In response to these challenges, our participants also discussed various ways to access funding, including an annual internal budget or external opportunities such as the Louis Stokes Alliance for Minority Participation (LSAMP), and the NSF Scholarships in Science, Technology, Engineering, and Mathematics Program (S-STEM). Furthermore, other programs such as HHMI SEA-PHAGES (Science Education Alliance-Phage Hunters Advancing Genomics and Evolutionary Science) and SEA-GENES (Science Education Alliance-Gene-function Elucidation by a Network of Emerging Scientists) provide curricular and professional development support for implementing CUREs.

Identifying mentors

Another common challenge to facilitate undergraduate research was the ability of institutions and programs to identify and recruit interested faculty mentors. This category is not independent of the previous discussion about funding as faculty members often have full schedules of paid and unpaid duties with little room for the time-consuming task of training and mentoring a research project. Without an incentive for faculty to build a strong program that includes undergraduates, they are unlikely to prioritize taking on such a demanding endeavor.

Two primary ways for undergraduate students to identify mentors emerged in the sample: divisions or organizations dedicated to campus-wide UREs and less formal initiatives housed in specific departments, under faculty, or connecting students with online resources. Centers for UREs often have dedicated staff who serve as a resource for students interested in undergraduate research and, therefore, have reliable funding. However, less than one-fourth of our sample had a formal center on campus that facilitated cross-disciplinary research opportunities ranging from research symposiums and festivals to workshops and funding opportunities.

On the other hand, many of the smaller schools in the sample tended to loosely facilitate undergraduate research. These efforts differ from the centralized ones discussed above, in that they are more of a traditional approach to URE and a piecemeal approach involving certain departments or faculty. These efforts often existed as online resources directing students to online workshops for identifying and approaching a mentor, a database of on-campus research opportunities, or links to external funding opportunities. For example, one participant mentioned their infrastructure was "very *ad hoc*. Students reach out to faculty on their own." By infrastructure, we mean the formal and informal programs that facilitate undergraduate research at the institutions. "Formal" infrastructure to us meant formal programs specifically designed to support students (i.e., LSAMP and McNair Scholars). "Informal" or "*ad hoc*" infrastructure meant that there were no formal programs and that undergraduate research relationships were built between individual students and faculty without any institutional support.

Student recruitment and engagement

Student recruitment and engagement refers to first making students aware of research opportunities on campus and then developing interest and maintaining engagement, ideally resulting in a research opportunity for the student (16). Attendees mentioned how some students are unaware of the existing opportunities on campus or how to access positions in research labs. Although engagement and motivation of students once they arrive in the classroom and laboratory have frequently been considered in the literature (16), fewer resources have explored ways to recruit such students in the first place.

Through our search of program websites, we noticed that some institutions had multiple locations on the website hosting UREs, such as a microbiology lab opportunity on a department website and a URE funding source resource on the library's page. At these institutions, there was no clear "hub" for UREs and no clear place for interested students to start. Additionally, the various centers and their acronyms could be confusing. Many of these pages were also outdated, with listed funding opportunities on two websites having expired in 2015. Without URE hubs on campus, students may find it challenging to locate URE opportunities, and faculty in different departments may be duplicating efforts by applying for grants intended to spearhead research on the same campus. A central URE hub could support more collaborative efforts between faculty and students.

Diversity, equity, and inclusion

Many of problems require cross-cultural, cross-political, and diverse perspectives to address adequately, suggesting that tenets of diversity, equity, and inclusion should be a central tenet of URE design to produce a diverse STEM workforce (17). UREs can help move the needle to ensure we have a diverse STEM workforce (7, 8). For instance, Estrada et al. (4) found that undergraduate research experiences in the junior and senior years of college were positively associated with students' science self-efficacy and science identity (4). However, targeted efforts to recruit diverse students are often not the focal point of UREs (4). Only two of the programs in the sample were found to allocate funding to or prioritize funding for underrepresented minorities. One participant mentioned their program does target individuals from underrepresented groups in STEM. Notably, both programs were funded by sources that required attention to this area.

Early skill development

Undergraduate research mentors have often lamented the lack of laboratory skills undergraduate students possess when seeking to enter a lab placement (18), and this appeared in our sample as well. One participant mentioned the importance of "[getting] students excited and trained on some lab basics, like pipetting." Another mentioned that "many faculty don't want to train students to do lab work, but students don't take our lab classes until junior year." This suggests that faculty perceive a lack in students laboratory skills, which the faculty would prefer the students have before entering their lab. Other participants also indicated the importance of getting students "into the lab and trained up with a core skillset" and suggested a "boot camp" to get early-career college students trained with laboratory basics.

Without a systematic impartment of the basic laboratory skills and the scientific method, mentors must dedicate their own time and resources to train students. UREs (including CUREs) alleviate this problem by imparting the necessary skills in the normal classroom setting to a class of students at once (16), usually in their first year or two. However, only one institution in the sample had a URE that targeted skill development in early-career undergraduate students.

Conclusions and next steps

Our survey results suggest that institutional efforts to foster undergraduate experiences differ considerably between institutions, and much more work is needed before "best practices" can be identified. While much research has called for the rigorous assessment of CUREs and other UREs (11, 15, 16), there is also the need to inform those interested in spearheading or expanding UREs at their institution that there is no one-size-fits-all approach, and many options exist for facilitating these opportunities. We encourage those who are interested in fostering these efforts to reflect on their institution and adopt or design an initiative that will meet their unique needs and overcome historic barriers. Our findings from this work indicate several challenges associated with UREs; however, we have also presented potential solutions and presented all of these in Fig. 1.

The experience of implementing collaborative UREs across chemical biology, biochemistry, and neurobiology was detailed in a study noting the balancing act that faculty interested in facilitating a URE must navigate between their teaching and research duties (not to mention service) and the time- and energy-consuming process of lab design and program implementation (including evaluation) (15). The time and effort involved in CURE design and facilitation, with a section devoted to the fear of identifying a research topic, were also highlighted as barriers to implementing CUREs in a guide that offers strategies to overcoming barriers and fear of the CURE and other CURE literature (13, 17–19). Another challenge regards developing a research idea that can fully involve a class of early-career researchers and be accomplished in one semester. In 2019, a study gathered the perspectives of graduate teaching assistants involved in CURE instruction and identified the challenges of "academic unreadiness of first-year undergraduates" (18), logistics, motivating students to take ownership, and time. A review of faculty perspectives produced similar findings of challenges regarding logistics, time/work investment, financial restraints, a CURE-compatible research topic, overall project uncertainty, and student resistance to the uncertainty (13). Other challenges to CUREs include the financial cost and fostering buy-in from all necessary partners, including the institution, faculty, and students.

Financial constraints have been a common theme for challenges for UREs (13). Funding for UREs breaches every categorized barrier, perhaps positing it as the starting point for meaningful UREs. Incentives should exist at the institutional level for faculty to seek funding to sponsor UREs, and better yet, institutional administration should be targeted to include a reliable URE budget. The participants in the breakout session identified several funding programs that support CUREs and other UREs, including LSAMP. Faculty, staff, and administration should be educated on the research-based benefits of UREs and made aware of the barriers that exist so that they can plan to navigate them from the beginning.

Furthermore, DEI efforts were seldom mentioned or found on the institutions' websites. Given the ample evidence that evidence-based practices, particularly UREs, support underrepresented students' persistence in STEM and professional development (4, 5, 8), this should be made a priority for anyone seeking to implement UREs. This is aligned with the funding mentioned above, in that some calls for supporting UREs specifically target URM students (i.e., LSAMP). Efforts on campuses should support faculty to develop proposals to support these programs for URMs.

In addition to identifying challenges, our participants also proposed solutions for overcoming some of the challenges. Some of the most innovative ideas we saw included centralized online databases where mentors register and can be searched by interested students. These databases were present on campuses both with and without formal URE centers and seem to be a good first interdisciplinary step toward connecting faculty across disciplines with undergraduate students.

The findings reported in this position piece highlight the real experiences of faculty attempting to implement UREs for their students. In these discussions, we highlighted the challenges and potential solutions to overcoming these challenges. As the implementation of UREs ranges from campus to campus, we support the call for further evaluation of these diverse programs. Both qualitative and quantitative approaches should be used, and the discipline would benefit from cross-campus program comparisons.

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ETHICS APPROVAL

The data collection from the survey and breakout session was approved by the TTU Institutional Review Board (IRB) committee (IRB2021-504).

ADDITIONAL FILES

The following material is available online.

Supplemental Material

Supplementary Material 1 (jmbe00099-24-s0001.docx). ASMCUE Survey (participants were offered this survey and made aware that breakout room discourse and survey responses would be used in a publication as part of an assessment of undergraduate research infrastructure).

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