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Research experiences for undergraduates (REUs) are an important component of undergraduate education. However, at the 2012 Trends in Undergraduate Research in the Mathematical Sciences conference, questions were raised about why many REU programs see few applications from students that are members of underrepresented groups. We examine the benefits of REUs and factors preventing or promoting participation in REUs.

Research experiences for undergraduates (REUs) have become an important component of undergraduate education. An REU gives students the opportunity to work independently or in small groups on challenging problems, present to a mathematical audience, and communicate findings via technical writing that is often published. Considering the many aspects of professional and academic life addressed by REUs, it is no surprise that research experience is highly valued by both graduate schools and employers.

Perhaps more importantly, REUs play a key role in encouraging students to pursue careers in science, technology, engineering, and mathematics (STEM) fields in the first place. Indeed, surveys of former math REU students indicate that REUs "nurture the commitment of a student to pursue a career in mathematics" [Connolly and Gallian 2007]. Despite the demonstrated effectiveness of the many REU programs currently in operation, the number of students entering STEM areas — in particular, mathematics — remains very low. The February 2012 issue of *Notices of the AMS* showed that the number of undergraduate degrees in mathematics awarded annually decreased 5% from 2006 to 2010. A report by the President's council of advisors in science and technology states that in order to maintain its "historic preeminence" in STEM fields, "the United States will need to increase the number of students who receive undergraduate STEM degrees by about 34% annually over current rates" [PCAST 2012].

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Increased participation by underrepresented groups "is critical to ensuring a high-quality supply of scientists and engineers in the United States over the long term" [Hartline and Poston 2009]. "Women, underrepresented minorities and persons with disabilities comprise more than two-thirds of the U.S. workforce, but hold only about one-quarter of the science, engineering and technology jobs that underpin U.S. economic strength" [NSF 2003]. Moreover, the groups that are most underrepresented in STEM fields are within the fastest growing segments of the general population [COMURG 2011].

It has been suggested that one way to increase the rate of graduates in STEM fields is to diversify teaching methods [PCAST 2012]. REUs, which have been shown to improve retention and academic achievement, are a key demonstration of this principle [Osborn 2009]. It would stand to reason, therefore, that involvement of more underrepresented students in REUs could play a critical role in achieving the suggested 34% increase in STEM degrees. Accordingly, many REUs have included diversity aspects in their program designs.

An open discussion at the end of the 2012 Trends in Undergraduate Research in the Mathematical Sciences (TURMS) conference raised the question of why some REUs are receiving very few applications from students in underrepresented groups. As the conversation proceeded, it became clear that this is an issue that mentors at the REU students' home institutions as well as REU organizers find significant. This article examines how we might go about increasing participation in REUs from students in underrepresented groups. Here we expand the umbrella of underrepresented groups (URGs) to include "minority, low-income, first-generation, and disabled students" [Osborn 2009] each of which is indeed underrepresented within the STEM workforce. Appealing to input from colleagues, published research, and our own personal experience, we examine the issues that might prevent students from URGs from participating in REUs as well as what we can do to change this.

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1. Benefits of a successful REU experience: stakeholder perspectives

Before considering how to better recruit students from URGs for summer research, it is beneficial to look at what is most important to the students we want to encourage, to their mentors at their home institutions, and to the REU organizers. For all three of these stakeholders, there are some additional expectations for a good REU experience that go beyond those that we most frequently consider.

Benefits that students gain from REUs can be (more or less) organized into the following four categories: gains in knowledge, academic achievement, professional

advancement, and personal growth [Osborn 2009]. Students from URGs, like all students, expect an REU to provide them with knowledge, experience, and skills in mathematical research, but they also may need more emphasis on professional and personal growth. Particularly of interest to many students from URGs may be developing "stronger relationships with mentors and other professionals" and "deeper integration into the culture and profession of the discipline" [Osborn 2009]. Merging the sphere of academics with the social and family spheres is also often important [Webb 2009]. "Program components that encourage social interaction and link academic pursuits to community are often more important to historically underrepresented students and women than to other students" [Gregerman 2009].

Mentors from a student's home institution look to REUs to provide experiences for their student that cannot be obtained during the academic year. Students from URGs are more likely to have deficits in their academic background. First-generation college students may be particularly in need of information and resources related to graduate school or employment for mathematicians. Also, especially important for many students from URGs is the formation of an REU cohort. Through this cohort, students gain the experience of socializing, learning, and professionally interacting with others from URGs.

Because students from URGs "experience differential retention rates and inequities in academic achievement" [Bauman et al. 2005] mentors hope that having their students attend REUs will produce a halo-effect within the entire department. Ideally, these students will return to college with a newfound intellectual vibrancy and maturity, which greatly enhances the intellectual climate of a department and also improves retention. "A collaborative scholarly and creative atmosphere attracts motivated students, talented and committed faculty and staff members, and devoted trustees, all of whose involvement further advances the overall academic program of the institution" [Osborn 2009]. This is especially of interest as the amount of government-based funding for REUs has decreased, and we are looking for sustainable ways to increase the production of STEM graduates. The more effective the REU experience, the more likely other students in a student's academic sphere will be impacted.

REU organizers are interested in expanding opportunities to mentor, teach, and conduct research. They are also interested in effective ways to combine scholarship with teaching [Osborn 2009]. For REUs focused on engaging students from URGs, there are additional benefits. At present, funding agencies prefer to support programs that mentor students from URGs. Beyond possible increased funding benefits "mentoring underrepresented students allows faculty members to foster connections with a wide range of campus offices, better integrating undergraduate research into the institutional culture" [Osborn 2009]. These interactions are a benefit to all students participating in REUs. In addition, developing the talents of students from

URGs will increase the pool of prepared candidates that intend to pursue STEM careers.

2. Factors preventing involvement in REUs

The previous section highlighted some of the specific benefits stakeholders (students, their home institutions, and the REU programs) are seeking with regard to involving students from URGs in REUs. Here, we attempt to point out factors — both logistical and psychological — that could be contributing to a lack of applications from students in URGs. In addition, part of the perceived lack of applicants may be because applicants tend to cluster at particular REUs.

For many students from URGs, mentors at the home institution may have a strong influence on the programs their students apply to. Some colleges actively recruit minority students and involve them in programs geared towards helping them succeed. Generally, part of this involves encouraging students to pursue extracurricular intellectual activities like REUs. A recent article addresses the issue of faculty members placing their students in REUs noting that "faculty members at these institutions are highly protective of their students and highly selective in making recommendations to students regarding research opportunities" [Evansech 2009]. If an REU does not stand out to a mentor as a program where his or her student is most likely to have a successful and positive experience, it is unlikely the student will be encouraged to apply.

Many students from URGs do not have access to advanced classes in mathematics during high school. For this reason alone, they are less likely to stand out as good candidates for REUs. These students are less likely to declare a major in a STEM field; in fact, they are more likely to have no major upon entering college [Chen and Carroll 2005]. Even if these students are enrolled in mathematics classes at four-year institutions, they often come into college underprepared and may not complete calculus until their second year [Biermann 2009]. Students from URGs are also more likely to begin postsecondary education at a two-year institution, which may also limit their opportunities to find out about REUs.

Even if students are aware of REU opportunities, they may be intimidated by the process of selecting and applying for programs. A publication from the Council on Undergraduate Research (CUR) on mentoring undergraduate researchers notes that "students can become overwhelmed when they do not receive the support they need, and are often reluctant to ask for assistance" [Temple et al. 2010]. This is especially true for many students from URGs who may experience social and academic isolation and lack of confidence in their abilities. "Even if students are prepared and interested, they and their families may be intimidated by the higher

education environment in which they have had little or no previous interaction" [COMURG 2011].

Students unfamiliar with the details of REUs may not understand that applications are competitive; this can result in weak applications that may not be given serious consideration. For the students who do seek help in crafting application materials, campus career services and writing centers may cover writing style and grammar, but sometimes miss the mark when it comes to the more technical writing required in STEM disciplines. Since mathematics courses do not always have a large writing component, the students may not realize that strong writing skills are expected by REUs. Talented mathematics students that struggle with writing skills are less likely to stand out as promising REU applicants.

Students from low-income households are more likely to be working while in school. This means that they will be concerned about leaving jobs to pursue summer research [Watkins 2009]. It is often the case that students are willing to participate in an REU as long as the stipend is comparable to their standard income. However, students unfamiliar with the structure of an REU often assume that REUs, like many summer internships, are unpaid. If a student has children or a spouse, the situation becomes more complicated, since attending an REU could mean losing health benefits and childcare.

3. Promoting more applications from students in URGs

One easy thing mathematics professors can do to promote more applications from students in URGs is early and often to encourage *all* students that demonstrate an interest or ability in math to apply to REUs. We can try to emphasize participation in REUs as an essential component of the math major much as summer internships are for students in other STEM disciplines.

Students who are unfamiliar with REUs sometimes do not know what they should be looking for, and this makes it difficult to apply to the right programs. In order to minimize confusion while also easing the strain on already busy professors, we suggest drafting a document outlining the steps for applying to REUs. The components of such a document may depend on the students it is geared towards but might include information about what an REU program entails, what to expect from an REU, advice on gauging one's own eligibility and needs, choosing programs, and putting together competitive applications. Resources such as contact information for students that have attended REUs in the past may also be helpful. Clearly communicating the expectations for applications will hopefully reduce intimidation and give students from various backgrounds a better chance of getting into an REU and succeeding in the program.

REU organizers can attract a more diverse applicant pool by making sure their program websites are accessible and welcoming to nonexpert undergraduates. In surveying colleagues from various educational institutions, we conclude that students are often the ones reading REU websites. Professors, who are extremely busy during the semester, will give interested students the NSF-REU website or other resources but leave it to the students to investigate individual programs. Overly technical project descriptions and large blocks of text that read like excerpts from grant proposals may be particularly intimidating. Especially where an REU is trying to attract students that have not yet experienced the culture of mathematics, websites and promotional materials should be carefully constructed with the undergraduate perspective in mind.

Another effective method for attracting students from URGs is to reach out to minority-serving institutions such as historically black colleges, Hispanic-serving institutions, and other similar institutions. Mathematicians who have been nationally recognized for their interests in building diversity are also great resources and advocates. It is helpful to promote REUs by connecting with organizations that serve URGs, such as the Society for the Advancement of Chicanos and Native Americans in Science (SACNAS), the American Indian Science and Engineering Society (AINSES), the National Association of Mathematicians (NAM), and the Louis Stokes Institute [Vélez 2011].

It is also essential for REUs to keep in mind that students' institutional mentors are interested in activities and programs that go beyond mathematics. Mentors of underrepresented students want to know that their students are likely to succeed in a particular REU; they are looking for language beyond the tagline "minorities and women are especially encouraged to apply". Key activities should include providing social support and assisting students in navigating a new environment. One way for REU organizers to provide more of these programs is to increase coordination within campuses and regions. Since diversity is such an important aspect of undergraduate education, there is usually a range of opportunities on campus. Mentors are also looking for signs of inclusive excellence, which the literature defines as programs "integrating their diversity and educational quality efforts" [O'Neill 2009]. All students will benefit from socializing with a more diverse group and participating in integrating activities, and these should be highlighted in REU program descriptions. In other words, mentors are looking for an REU to exhibit dedication to helping all students, regardless of background, do superior work.

As part of the ongoing discussion on this topic, Tamas Forgacs surveyed TURMS participants, asking what information would make them more likely to send their students to a particular REU. The following is a compilation of the responses.

(1) Strict and quantified criteria to be met for a given REU program. For example, if a given program scrutinizes GPA and courses taken, what is the minimum GPA and what courses are required?

(2) How research mentors are trained and selected.

(3) What the daily schedule is (how accessible is the mentor, how many meetings, etc.).

(4) What kinds of community-building activities there are.

(5) How the students are chosen — is it only the top tier or is there an effort to reach out to the promising students?

(6) Total number of applications/total number of offers made (in years past).

(7) The institutions, year in school (freshman, sophomore, junior) and mathematics GPAs of students admitted.

(8) The sex and race of students admitted.

(9) The sex and race of research mentors.

4. Conclusion

The United States is in need of more STEM graduates. While its population is becoming increasingly more diverse, the fastest growing segments are also the least represented within STEM fields. REUs are transformative experiences that provide students with motivation, experience, and mentorship. Reaching out to a larger group of REU candidates will provide immediate career goals and achievement benchmarks for all students. For this reason, an increased number of underrepresented students participating in our REUs could translate to an increase in the STEM workforce.

Well mentored minority students are often encouraged by their mentors to apply to specific REU programs. These programs, like all REUs, have a limited number of positions. This may mean that there is increased competition among minorities to attend some programs while other programs are getting very few applications. Students that are not mentored may not know about REUs or may be submitting subpar applications.

We conclude by summarizing our suggestions for increasing the number of applications from URGs to REUs.

For home institutions:

- Encourage all students, early and often, to consider REUs.
- Draft a document that informs students about the benefits of REUs and guides them through the process of selecting and applying for REU programs.

For REU organizers:

- Make program websites accessible and inviting to an audience that is not mathematically advanced.
- Highlight activities that go beyond academics to provide social support.
- When possible, partner with other campus programs that are geared towards diversity to improve the student experience.
- Make statistics about previous participants of the REU available to students and their mentors.

For everyone:

- Reach out to advocates for URGs to help connect students to the right programs.

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