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Challenges in promoting undergraduate research in the mathematical sciences

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We describe the challenges in promoting undergraduate research in the mathematical sciences. The challenges are grouped in regards to the population that research is promoted to: students, faculty and administrators. For each category, we provide some suggestions for overcoming the challenges taking into account the variety of institutions involved.

1. Introduction

The benefits of implementing strong undergraduate research (UR) programs across the sciences have been investigated in some depth by several authors [Karukstis and Hensel 2010; Laursen et al. 2010; Lopatto 2009; Seymour et al. 2004]. However, the progress towards implementing robust UR programs in the mathematical sciences has been slower than it has been for the other sciences. It has been especially difficult to integrate research into the undergraduate mathematics curriculum. In improving the UR landscape in the mathematical sciences, each of the three constituents — students, faculty (including both faculty to serve as mentors and other mathematics faculty) and the administration — can play a significant role. To get support from these constituents, UR and its benefits has to be effectively promoted to them.

In this article, which grew out of the discussions during the "Challenges in Promoting Undergraduate Research" session at the TURMS conference, we discuss the challenges in promoting UR to each of the three audiences and offer some suggestions for how to overcome these challenges. Throughout, we use "undergraduate research" to mean the following definition, provided in [CUPM 2006]:

- The student is engaged in original work in pure or applied mathematics.
- The student understands and works on a problem of current research interest.

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- The activity simulates publishable mathematical work even if the outcome is not publishable.
- The topic addressed is significantly beyond the standard undergraduate curriculum.

This expands upon the definition by the Council of Undergraduate Research, which is "an inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline".

2. Challenges in promoting undergraduate research to faculty

Supervising a UR experience may feel like an enormous task for many faculty. In particular, coming up with appropriate topics and problems can be a major source of difficulty. Rarely can mathematics faculty simply give their students the problems that they are working on and expect a meaningful and substantial contribution. Doing so puts students in an untenable position. Instead, faculty should formulate problems that are both relevant to their research agenda and, at the same time, accessible to talented undergraduate students after a brief tutorial on relevant background material. Put another way, in discussions on UR it is important to keep in mind that the word "undergraduate" is an important qualifier.

However, keeping in mind the definition, a UR experience should be original work in pure or applied mathematics which the student understands. Discoveries that are new only for students cannot be classified as research. By keeping UR problems related to a faculty's main research interests, there is a much greater likelihood that the research will result in something of real value to both the faculty mentor and the student. The faculty mentor will be able to gauge student progress through the research project better and will know for sure whether the results are original research. For junior faculty, in particular, attending student presentations and reading papers written by students will help in developing a sense for the appropriate level of problems for students. A website with open problems appropriate for UR will also be useful in addressing this issue. If the level and the topic of the problems are appropriate, the faculty mentor will be able to get more value from the research experience.

Indeed, the value of UR for faculty is an extremely important concern. Faculty time is a precious commodity. Undergraduate students need effective mentoring for the duration of their project, and many faculty — especially pretenure — may not be able to justify spending this time if it takes away from duties that are perceived to have more value to their career advancement. In light of this, discussions on the institutional value of UR should be initiated at both the department and university level, and the outcome of these discussions should be formalized as much as possible with the appropriate university committees that decide on annual

evaluation, promotion and tenure. These discussions can also include how the faculty and students involved in research will be supported, funded and recognized.

A department which values UR should consider this work as part of the department's regular workload and the faculty members involved in UR should be appropriately recognized for their contributions in this area. Ideally all faculty members, whether they are involved in UR themselves or not, will promote the benefits of UR: to students, to other faculty and staff within the university, and to the mathematical community outside of the university. If there is a critical mass of faculty members involved in and promoting UR to others, the department is more likely to have an overall positive UR atmosphere.

Even in cases where the value of UR is recognized by the department and the university, there are many challenges that faculty face in mentoring UR, including recruiting students for research projects, finding additional time and resources for mathematically underprepared students, and finding additional time and resources for teaching auxiliary skills, such as typing in LaTeX, giving presentations, etc.

In a department with a critical mass of faculty interested in UR, collaborating on certain aspects of the student preparation can alleviate the workload. For example, instead of individual faculty members teaching their own students LaTeX, students can participate in LaTeX workshops. Faculty can also collaborate on and support each other in grant writing activities.

3. Challenges in promoting undergraduate research to students

Students who participate in research are overwhelmingly excited about the experience. However, the overall student population is not generally enthusiastic or even well-informed about participating in research. Many students are unaware of the different levels and varieties of research options, or what these different options involve. Partly due to this unawareness, some students have the perception that they are not adequately prepared or talented enough to do research. This may also be because these students do not have confidence in their mathematical abilities, or because they do not envision enough benefits from a research experience. Students intending to go to graduate school in mathematical sciences are more likely to appreciate the benefits of UR. Yet, a research experience will also be extremely beneficial for preservice teachers and students intending to work in industry, and even for students intending to go to a professional school or nonmathematics students. Finally, nontraditional students with families or students who work close to full-time have a hard time fitting research into their regular schedule. So, what can we do to counter these issues in promoting UR to students?

A successful marketing campaign promoting UR to students will address most of the reasons contributing to low student interest. A variety of media are available

to reach the students, including classroom time, social media, newsletters, student club events, and word-of-mouth. Faculty members can use some of their class time to provide information on research opportunities and specific research project topics. Research opportunities and information on previous student participants can be announced in print or online media targeting students. Examples include Facebook student groups, Twitter posts, web pages dedicated to UR opportunities, and newsletters and emails sent to students. Department seminars provide venues for students to present their own research and to learn about others' work. During seminars and student club meetings, students can also be informed about general logistical information such as what UR means, when students should apply, which materials are needed for an application, sample UR topics by the department faculty members, and other related information. Students especially appreciate receiving individualized information from faculty members and advisors during one-on-one conversations. A student will be more convinced of the benefit of research if multiple faculty members mention the opportunity. Additionally, a personal invitation and encouragement from the faculty supervisor of a specific project carries more weight for a student. Although we listed several suggestions, it is important that in each department the faculty study their students carefully and use marketing tools appropriate for their audience.

The success of a marketing campaign also depends on creating a community among students in which the positive messages about UR are reinforced through peers. Enthusiastic personal reports from students who participated in research presented through panels, seminars, student club meetings, newsletter articles, and other venues will strengthen the messages students receive from faculty and administrators. In smaller schools where these role models may not exist, students can participate in conference trips to network with students from other schools who participated in research. Faculty members also play a significant role in helping the student community value UR. When faculty members agree that UR is valuable, this value will be reflected in their interactions with students.

Interest in UR can also be increased by providing various perks to students. To help create a community of scholars within the department, conference and seminar attendance can be encouraged through extra credit or professional development credit in classes. Active faculty participation in these events will facilitate building a community of scholars among students. Research can be incorporated into the curriculum through optional or required independent studies, research/seminar courses, or capstone courses with research components. Receiving college credit for research will provide students with documentation of their work on their transcripts. For students with financial needs, making them aware of funded research opportunities will allow them to pursue research instead of having to work. Keeping the research project schedule flexible will help students with families to participate

in the experience. Finally, for students going into teaching or industry jobs, faculty must strive to make it clear that research experiences are beneficial to every student. During a research experience, students sharpen their critical thinking, lifelong learning, communication, and problem-solving skills, all of which are highly sought by employers. Students also develop a close professional relationship with their faculty supervisor which will help them receive a better and more detailed recommendation letter from this faculty supervisor. These nongraduate school track students might be further motivated by research projects that focus on mathematics education, applications of mathematics or industrial problems.

4. Challenges in promoting undergraduate research to administrators

Administrative support is the key to overcoming the challenges related to promoting UR to faculty and students. Faculty participation in UR in both numbers and time will be higher if faculty's UR work is rewarded and encouraged by the administration. Similarly, students will be more motivated to participate in research if there is a clear articulation and endorsement of the benefits of UR by their institutions. Administrative support in the form of tangible funding is also critical for internally run UR programs. Finally, a certain degree of institutional support is also required for incorporating UR in the curriculum.

In order to increase administrative support for UR, the benefits of UR can be described in relation to the standard measures of university success, such as recruitment, retention, and job/graduate school placement. As one of the "high impact practices", UR is shown to have a positive effect on all of these measures, especially the retention and overall academic performance of minority and first-generation students [Barlow and Villarejo 2004; Ishiyama and Hopkins 2002]. These results will support the case for UR in the eyes of administrators. It would also be very helpful to obtain external support in the form of letters from alumni (reflecting on importance of the research experience in their careers), letters of support from industry as well as colleagues from other schools and departments. When communicating the importance of UR to administrators, the following points for each of the main measures can be made.

Recruitment. Prospective students look for a college experience that will be unique and exciting. Participating in research as an undergraduate is an attractive feature. It signals close interaction with faculty and individual attention paid to the students. Mentioning these opportunities in university advertising materials and in various communications with prospective students will help recruit highly qualified students to the university. Smaller institutions that can provide research opportunities to most of their students, possibly as part of their curriculum, can use these opportunities to lure students to their institution and to the mathematics major.

Retention. Undergraduate research provides students the opportunity to discover and/or nourish their passion for research, to receive individual mentoring from faculty members and to meet other people as excited as themselves about mathematics. Close relationships with faculty and other mathematics majors built early in a student's studies help students to stay in school and in the mathematics field. Through these relationships a student receives personal encouragement to continue in the mathematics field, and learns more about career opportunities for mathematics majors in academia, industry and government, and how to be successful in mathematics, all of which positively impact a student's interest and success in mathematics. The excitement and pride a student feels in the process of discovering mathematics also positively affects the students chances of continuing in mathematics and at the institution they are at.

Job placement. Mathematics graduates typically choose one of three career directions. They might go to graduate school, teach in K–12, or find employment in industry. A UR experience will help students get into better graduate schools. UR experiences make preservice teachers highly marketable in places where the job market for teachers is tight. Finally, employers outside of academia also highly value UR because it shows that the student has intellectual curiosity, can work with others, and has analytical skills as well as experience in problem solving.

Once the positive effects of UR on the important university success measures are demonstrated, it will be easier to get administrative support. The first and foremost type of support that faculty needs is the recognition of the UR work in the promotion, tenure and annual evaluation processes. Especially untenured faculty will be unmotivated in supervising UR projects if this work will not be valued in the tenure process. By the time the faculty member is tenured, it might be too late for this faculty member to be motivated to start a UR program from scratch. In addition to recognizing UR in personnel reviews, many tangible benefits can be provided to faculty members. If the administrators truly acknowledge the benefits of UR and the university has funding, they will be willing to provide funding to faculty and students engaged in research. If budget constraints do not allow monetary support, the administrators can provide other tangible benefits to faculty. Some examples of such support would be offering course release to faculty in exchange for supervising a certain number of projects/students and extra travel funds to faculty supervising UR projects.

In promoting UR to administrators, mathematics faculty also need to place special emphasis on describing differences of UR in mathematical sciences and the other disciplines. The CUPM report [CUPM 2006] has a section highlighting these differences and can be very useful during conversations with administrators.

In conclusion, most of the challenges of promoting UR arise from not having the benefits of UR widely known among all parties involved. Continuous administrative

support will allow faculty to be more committed to and students to be more interested in UR. Many faculty already inherently believe that UR is beneficial to students, but administrative support, coupled with an awareness of benefits of UR, will help more faculty to be more invested in UR. On the student front, an awareness of UR benefits and opportunities will convince more students to pursue these opportunities, even to the extent that they become advocates of UR in the future when they become faculty members or university donors. A lot has already been accomplished in putting UR in mathematical sciences on the agendas of most departments and universities, but we still have more to do to expand the scope of UR to include more faculty and many more students.

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