involve
a journal of mathematics

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msp

2014 vol. 7, no. 3

INVOLVE 7:3 (2014)
dx.doi.org/10.2140/involve.2014.7.377

Alternative resources for funding and supporting undergraduate research

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(Communicated by Darren A. Narayan)

At a time when funding for programs on academic campuses around the country is tight, financial support for undergraduate research has also become increasingly difficult to find. We discuss some suggestions for funding and supporting undergraduate research programs in mathematics from the 2012 "Trends in Undergraduate Research in Mathematical Sciences" conference held in Chicago, October 26–28, 2012.

1. Introduction

The "Trends in Undergraduate Research in Mathematical Sciences" (TURMS) conference was held in Chicago, October 26–28, 2012. Members of the mathematical community came together with the common goal of fostering research programs in mathematics for undergraduate students.

At a time when funding for programs on academic campuses around the country is tight, financial support for undergraduate research has also become increasingly difficult to find. Funding for Research Experiences for Undergraduates (REUs) has traditionally come from the National Science Foundation (NSF). However, with the NSF facing budgetary constraints in the coming years, funding for REUs is uncertain and the number of REU sites has remained relatively flat over the last few years despite increasing interest from institutions wanting to host such programs. Jennifer Slimowitz Pearl, program director in the Division of Mathematical Sciences at the NSF, stated at the conference that the demand for REU funding from the NSF currently exceeds the ability to fund programs. She went on to say that currently there are great proposals that go unfunded simply for the fact that there is not enough room in the budget to support them. Furthermore, the budget for 2013 is not expected to increase. It is therefore necessary for institutions interested in funding undergraduate research to explore doing so by obtaining funding from sources outside of the NSF.

MSC2010: 97-06.
Keywords: undergraduate research.

Some government organizations, such as the Department of Defense, contribute funding for undergraduate research. These organizations give funding to the NSF instead of awarding grants directly, and it is the NSF that decides on and awards this funding to institutions. Representatives of the NSF have stated that they would be willing to work with additional organizations in this manner.

Some participants of the TURMS conference asked NSF representatives if it would be possible for host institutions to cost-share on REU expenses with the NSF. The representatives answered this question in the negative. One reason behind this decision is concern that the success of a proposal would be based on the amount of institutional cost-sharing in the budget and not necessarily the merit of the proposal.

In this article we describe possible answers and potential challenges to two questions of Pearl during her presentation in the opening banquet of the 2012 TURMS conference:

- How can undergraduate research be assimilated into the curriculum without outside funding?
- How can funding agencies structure an initial investment in an undergraduate research program (REU or otherwise) so that some parts of it are sustainable after the grant money ends?

2. Research in the curriculum

Many participants of the TURMS conference shared their experiences incorporating undergraduate research as part of the mathematics curriculum, both as explicit research courses and senior theses, or as courses centered around a model of inquiry-based learning. We present some discussion on both of these models in this section.

Research as a graduation requirement. One example where undergraduate research has been included as part of the curriculum is at East Tennessee State University (ETSU), where all math majors must complete a one-semester undergraduate research course. Anant Godbole, former math department chair at ETSU, explained that this course is possible both by the relatively small number of math majors and the willingness of faculty to advise projects in addition to their usual teaching responsibilities. At ETSU, Godbole reports that about half the faculty have volunteered to advise at least one student. The research experiences range from projects resulting in publications for the most able students to novel presentations of fundamental mathematical ideas for weaker students. Godbole reminded the group that even "C" students have to complete the course and these students also deserve a suitably challenging project. Another participant from Wartburg College mentioned that the Physics department there tried a similar model but found that

the effort needed to run such a program was unsustainable. At some liberal arts colleges, a research-type experience is also a graduation requirement. For instance, at Harvey Mudd College, mathematics majors must either complete a senior thesis or participate in a clinic project, a team project where students consult for an outside company to solve a real-world problem over the course of a year.

Inquiry-based learning. Inquiry-based learning (IBL) can be used as an educational tool to help students gain research experience in the classroom without the manpower needed to implement the ETSU model. Michael Starbird, professor at the University of Texas at Austin, proposed that IBL courses share many of the same learning outcomes with undergraduate research. In an IBL course, students are asked to work on problems to develop concept knowledge and problem-solving skills. At the end of a well organized IBL course, students should develop an ability to understand a research question, find strategies to solve a problem, work in teams, and learn how to raise questions in the process. Such IBL courses could serve as mini-REUs and translate research experience into the classroom. Incorporating IBL techniques into an undergraduate curriculum can provide a cost-efficient way of introducing research skills to a wide audience who might not otherwise be involved in undergraduate research in mathematics.

IBL courses bring together students from different backgrounds and with a wide range of skill sets to work and communicate as a team to solve a problem. Such classes might not only attract mathematics majors but also students who are just interested in mathematics. Consequently, instructors have more flexibility to introduce interdisciplinary research questions in the course. IBL techniques might be implemented in many different courses. However, incorporating IBL teaching methods for some courses might be challenging. Developing an IBL course requires careful planning and preparation by the faculty member. Some research questions might not be suitable to capture the essence of an IBL experience and might not attract students' interest. Since IBL course registration is open to all eligible students, instructors might spend some time motivating and encouraging students during the term. In contrast, the REU selection process filters for students who are already motivated and interested in mathematical research. Starbird states that benefits of this program include that in an IBL class, each day students are "overcoming the unknown" and sometimes experiencing the "joy of success" of solving a challenging problem new to them.

3. Creating sustainable research programs

If funding for undergraduate research continues to be scarce, then mathematics departments wishing to foster undergraduate research will be forced to find sustainable sources of funding. Departments with graduate programs could use graduate

students as mentors for undergraduate research without placing additional financial burden on the institution. Research mentors could also look to the local community to find support for undergraduate research. Participants of the TURMS conference also brought up the concern for compensating faculty and students who participate in undergraduate research. We discuss these issues in the following section.

Graduate students as research mentors. While graduate students are not the sole mentors in many REUs, their participation is essential in organizing larger REUs with a variety of different research projects. The workload in maintaining a REU program for a large group of undergraduate students can be overwhelming. As Leslie Hogben, professor at Iowa State University, explained in her presentation, a graduate assistant serves as a bridge between the faculty mentor and the student research groups in the REU process. They make sure that students are meeting the expectations and working effectively in a collaborative environment. If there is a problem in the team dynamics, it has been Hogben's experience that students are more likely to share it with a graduate assistant than a faculty mentor. Students might also feel more comfortable talking to graduate assistants about graduate schools and mathematics as a career option. Serving as mentors in REUs will help graduate students to become better teachers and researchers in the future. During the term of the REU, they will discuss a variety of research topics with a diverse and wide audience. Such exposure early in their careers motivates them to improve their teaching methods, benefiting both the graduate students and undergraduate students at once. For a more detailed account of the benefits of graduate student mentors for undergraduate research, see [Bliss and Isaksen 2000; Hartke et al. 2007].

Community-based learning. If the federal government will not fully support undergraduate research, then the mathematical community must look to other sources of funding. One source of sustainable research problems and funding is community-based learning. In community-based learning local individuals or organizations consult with an institution and engage students to solve a problem related to their business or nonprofit organization. One benefit of this is that students get to work on real-world problems that directly impact their community. At some institutions, such as Davidson College, there is a Center of Civic Engagement that promotes courses that incorporate community-based learning assignments. They provide a small stipend (typically around $1500) to encourage faculty members to add community-based aspects to their classes and compensate them for the additional preparation time these projects entail. Organizations that come to an institution for advice may also be asked to provide support for students to present their work at an undergraduate research conference.

Another way students can receive an experience akin to mathematical research is through internships. At Worcester Polytechnic Institute there is a graduation

requirement where students of every major must participate in an internship or consulting experience with business partners either locally or through established global partnerships.

Compensation for student and faculty research. One major concern of many conference participants is that their current institutions do not have the funds or are unwilling to compensate faculty directly for work with students during the academic year. Even small amounts of monetary compensation can indicate to a faculty member that their efforts are appreciated by their institutions. One way that faculty can be rewarded is via the tenure and promotion process. Another suggestion was that students could be paid for conducting research as a form of work-study.

Departments may be able to receive funding from alumni and corporate sponsors. Darren Narayan, professor at the Rochester Institute of Technology, gave the example of getting JetBlue to sponsor student travel and asking alumni to sponsor a student. This approach could eventually turn into an endowed fund providing a perpetual and sustainable source for student research funding. It may also be the case that alumni are more willing to give when they see the direct benefit of their contribution. Narayan also suggested that it is more effective to contact alumni with opportunities to support student travel to conferences, with a tangible purpose of their donation. Faculty interested in these kinds of initiatives should coordinate with their development office.

4. Conclusion

The level of participation at the 2012 TURMS conference shows anecdotally how far undergraduate research in mathematics has come in the past two decades. Nearly 500 undergraduates presented posters at the 2013 Joint Mathematics Meetings in San Diego, California. Joseph Gallian [2012] states unequivocally that "more REU-like summer programs, more academic year opportunities for undergraduates to engage in research, and more undergraduates attending conferences and presenting" are the future. However, it seems that it will take greater effort to find funding for this research. Whether the money is to fund an REU site, to pay students and faculty for institutional summer research programs, or to help undergraduates and their mentors travel to conferences to share their findings, the mathematical community must be creative in seeking out this financial support. Inquiry-based learning-type classes could be used to help foster the same kind of problem-solving skills and senses of mathematical discovery that are the intended goals of undergraduate research. Reaching out to the community in the form of service-learning and internships could lower the burden on the institutions and the government.

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Received: 2013-01-05 Revised: 2013-04-17 Accepted: 2013-04-26

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Involve (ISSN 1944-4184 electronic, 1944-4176 printed) at Mathematical Sciences Publishers, 798 Evans Hall #3840, c/o University of California, Berkeley, CA 94720-3840, is published continuously online. Periodical rate postage paid at Berkeley, CA 94704, and additional mailing offices.

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involve
2014 vol. 7 no. 3