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Promoting Undergraduate Research in Mathematics**

Diversity Issues in Undergraduate Research

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1. Introduction

This article summarizes the presentations given by the authors on the panel "Diversity issues in undergraduate research" held at the conference Promoting Undergraduate Research in Mathematics. The panelists discussed the importance of involving underrepresented communities in undergraduate research in mathematics as a method for increasing their representation in the profession. Data on U.S. mathematics degrees (especially for underrepresented groups), effective recruiting techniques and successful program strategies were discussed.

2. Herbert Medina: Comments on Demographics of U.S. Mathematics Degrees

The percentage of U.S. Ph.D.s in the mathematical sciences awarded to U.S. citizens and permanent residents continues to decline. Indeed, by 2005 the percentage of doctoral degrees in the mathematical sciences awarded to U.S. citizens had dipped to 41%, the lowest that it has been in many years (perhaps ever) [**1**]. As a comparison, we note that it was close to 70% twenty-five years ago [**3**]. The percentage of degrees going to U.S. citizens and permanent residents has dropped from 65% in 1995 to 52% 2004 [**4**].

The declining number of undergraduates majoring in the mathematical sciences suggests that, without intervention, these percentages will continue their dramatic decrease in the next few years. For example, the number of undergraduate mathematics degrees awarded to U.S. citizens and permanent residents in the U.S. decreased from 14,771 in 1989 to 11,673 in 2000 [**2**]. The data strongly suggest that the country is not producing enough native mathematicians and that the country's dependence on foreign mathematical talent will continue to increase.

In discussions at this and other mathematics conferences, individuals in mathematical leadership positions at the American Mathematical Society (AMS), the National Science Foundation (NSF) and the National Security Agency (NSA) have expressed concern about the country's inability to meet its mathematical needs from within. This challenge leads one to ask the question, *Which groups within the country have not been tapped sufficiently to contribute towards the mathematical sciences?*

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There is no one answer, but there are easily identifiable groups within which the cultivation of mathematical talent has been largely absent. These are African Americans, Hispanic/Latinos, and Native Americans. Indeed, from 1993 – 2004, the percentage of U.S. citizen doctorates earned by members of these groups was 5.1% [**3, 4**]. By 2005, these groups made up 28% of the U.S. population, and by 2060 the percentage is projected to be 41% [**5, 6**]. There is a severe underrepresentation of doctoral degree recipients from these groups and the changing demographics of the U.S. population suggests that if the U.S. is to alleviate the shortage of U.S. citizens and permanent residents earning mathematics doctorates, then mathematical talent from these groups is going to have to be better cultivated. Perhaps a one can voice this concern by asking, *Can a country expect to be a scientific leader when 40% of its citizens do not contribute significantly to a field as important as mathematics*?

This observation leads one to the question of whether or not there is mathematical talent within these ethnic groups to cultivate. The answer is affirmative. While the number of total U.S. bachelor degrees in mathematics has been declining, the number of degrees awarded to members of these ethnic groups increased from 1,218 in 1989 to 1,682 in 2000 [**2**] so there is a significant quantity of students from which to find potential doctoral students.

Programs like the Summer Institute in Mathematics for Undergraduates (SIMU), which ran at the University of Puerto Rico - Humacao, have demonstrated that this last statement is more than an assumption. Indeed, SIMU served 115 students, 91% of them were Hispanic/Latino U.S. citizens from the U.S. and Puerto Rico; 59 of these were accepted to Ph.D. programs in the mathematical sciences; 23 were accepted to masters programs in engineering, mathematics or education programs; and 4 students were accepted to "other" graduate programs. Five of these students have already finished Ph.D.s; 21 have finished masters degrees; 45 are still in Ph.D. programs; and 8 are still in masters programs. Other programs, like the Mathematical and Theoretical Biology Institute (MTBI), a program that also targets U.S. ethnic minorities, also have enjoyed success with their students going to and completing graduate programs.

In the long-term, an overarching plan for dealing with the underrepresentation is for the entire U.S. mathematics community to identify early promising Black, Hispanic/Latino and Native American undergraduates and invest time, money and energy in developing and cultivating their mathematical talent. Certainly this practice, although perhaps not a coordinated effort, has resulted in significant progress in solving the underrepresentation of women earning doctorates in the recent past. Indeed, in 1991 21.6% of doctorates in the mathematical sciences awarded to U.S. citizens/permanent residents went to women; that had increased to 30.4% in 2005 [**3, 1**].

One idea on how to deal with the underrepresentation of certain groups in mathematics is to motivate the students and cultivate their talent through participation on undergraduate research. Suggestions of models and strategies to recruit, introduce and sustain minority participation on undergraduate research in mathematics are offered in the next sections.

3. Ricardo Cortez: Strategies for Introducing and Sustaining Minority Participation in Research

The fact that African Americans, Latinos and Native Americans, as a group, are severely underrepresented in higher mathematics leads us to ask the questions: *How are these students different from others?* and *What are the strategies that can increase the number of minority students in mathematics graduate programs?* Though the answers are not simple, a partial answer is that minority students often come from low income families, are first-generation college students who do not have family members or close friends that can advise them on graduate school, and have pressure to join work force as soon as possible. Here we describe a strategy for introducing undergraduate students from underrepresented groups to mathematics research and creating a network of advisors that mentors them over time and sustains their participation in mathematics activities that can ultimately place them in a more competitive position for graduate school. What follows is the collective experience of many people accumulated over more than 15 years through research programs for minorities such as the Summer Math Institute at UC Berkeley (1991-1997) and the Summer Institute in Mathematics for Undergraduates, SIMU, in Puerto Rico (1998-2002).

When to recruit: If the goal is to increase the number of well prepared students in mathematical sciences graduate programs, it is ideal to introduce the students to research during the sophomore or junior year. This allows enough time for the interested students to make appropriate adjustments to their remaining undergraduate classes.

The first research experience: Through an REU or some other research program, the students can have a rewarding first research experience. The topic of the project should be interesting and should not be limited to inconsequential projects specifically made for undergraduates. On the other hand, the projects must include challenges at various levels of difficulty so that there is a high probability that some results will be reached. Faculty can stress the difference between coursework and open-ended problems with no *a priori* answers. When possible, it is a good idea to stress the importance of basic courses to connect the students' classes with the research. The students must learn the importance of reading and communicating mathematics, while at the same time, discover that they meet the challenges posed by the project. Having students with a diverse academic background is helpful but students should not be underprepared for the program.

It is important to create the "right" atmosphere right away. Students have different expectations and often the wrong ideas about a research program. They are not used to doing math all day long. If the research program involves students from several universities, this will be the first time that many will compare themselves to peers from other schools. Consequently, some students will invariable intimidate others. In order to diffuse misconceptions, it usually helps to introduce cooperative learning, give them more work than any single student can do alone, and create groups that mix students with different academic backgrounds.

It is a good idea to start with the structure that undergraduates are used to (having specific assignments, problems with a clear beginning and end, having faculty ask the questions, etc.) and slowly reduce it. The students will have to make the transition to posing the questions themselves, dynamically adjusting the direction of the research, and dealing with open-ended questions. Starting from a

structure they understand and letting them know that a transition must occur is a good way to build self confidence.

One can take advantage of the students' inexperience with research to establish a work ethic that demands 15-hour days. It is surprising how the students accept this and make it a choice, especially when the projects are interesting and relevant to them and when they have resources available 24/7. This way, the students can be allowed to follow every lead and to discover which ideas pan out. Of course, the faculty mentor must lead by example. This is very difficult but the faculty must put in a similar amount of effort and dedication, be available at the time the students have breakthroughs and other proud moments.

All students have strengths and must be guided to find their role within the group. For example, some students are strong in analysis and others are strong in scientific computation. It is important that the students learn from each other and, at the same time, develop their own strengths. Getting to know them well helps to align the research challenges with their interests. The students will learn the balance between collaboration (exchanging ideas and developing synergy) and individual contributions based on their particular strengths. One word of caution is to never give students a false sense of ability.

As the faculty assumes the role of mentor to the students, the research program provides a unique opportunity to talk to them about graduate school options and research careers in the mathematical sciences. Many of the students will be hearing this for the first time and may not see themselves as graduate school material. Often students have misconceptions about the type of students who are competitive in graduate school and those who are unlikely to receive funding.

Introduction to a network of mentors: There are several organizations with strong mentoring components for students. Three societies of minority scientists that distinguish themselves in this area are the Society for Advancement of Chicanos and Native Americans in Science (`www.sacnas.org`), the American Indian Science and Engineering Society (`www.aises.org`), and the National Association of Mathematicians (`www.nam-math.org`). Hundreds of undergraduates present research posters at these societies' annual meetings which are also full of mentoring activities. Other opportunities for undergraduates can present their research and become part of a network of scientists are the Joint Math Meetings, the annual meeting of the Society for Industrial and Applied Mathematics (SIAM) and the National Conferences for Undergraduate Research (NCUR). It is a good idea to make it part of the research program for students to present a poster or give a talk at a national conference. During the conference, it is up to the mentor to introduce them to key people who will become part of their network of mentors.

Continuity in subsequent years: In order for students to continue along a successful path, it is necessary to stay in touch with them; to assist them to continue improving their reports to publishable level; to keep the students in mind for other conferences, programs, and fellowships; to continue talking to them about graduate school and offer to write recommendation letters; and to keep them as part of a large network of mentors.

4. Darren Narayan: Models for successful NREUP programs

A central goal of many REU programs is to encourage students to apply to graduate programs in the mathematical sciences. It is in these REU programs that

students get their first taste of mathematical research and discover their abilities for leading a successful career in the mathematical sciences. Currently the percentage of university faculty in mathematics that are African American, Hispanic, or Native American, is very small and a far cry from the demographics in the overall population. Inclusion of students from underrepresented groups in all REU programs is a critical step for increasing the number of minority faculty.

In 2003, the Mathematical Association of America launched the MAA National Research Experience for Undergraduates Program, which was designed to provide a research experience for students from underrepresented groups. The central goal of the program is to "increase undergraduate completion rates and encourage more students to pursue graduate study by exposing them to research experiences after they complete their sophomore year" [**7**]. Participation in an NREUP program can help make the student more competitive for acceptance into REU programs at other universities during ensuing years, and better prepare them for when they start.

Intelligent, well prepared, minority students are welcomed by REU programs, and as a result many of these students receive multiple offers. However less prepared minority students fare no better than less prepared students in general, and often find themselves not accepted into any REU programs. In order to boost the participation of minority students in REU programs, the pool of well prepared, mathematically talented, minority students must be increased. A strategy to do this is to invite minority students to participate in undergraduate research at their home institutions either during the summer or academic year. Not only does this provide an empowering experience for students, it also can serve as a means for discovering untapped potential. Some universities have internal funds available to support such endeavors. Externally funded programs include the MAA NREUP program and National Science Foundation REU Supplement grants. In addition to providing the student with their first research experience, the bond with a faculty member is also likely to be beneficial in terms of retention as well as in success beyond graduation.

It is also wise to also recruit minority students for undergraduate research in mathematics that are not mathematics majors, but are majoring in subjects where mathematics plays a central role, such as engineering, computer science, business, and management. The 2005 MAA NREUP program at RIT is an example of a successful undergraduate research program where two of the four students were not mathematics majors; one majored in electrical engineering, and the other in environmental management [**8**]. Including such students may encourage them to change majors once they discover their talents for mathematics, and the many career opportunities for mathematics majors.

The presence of minority students in all REU programs can not be underestimated. In order to increase the number of minority faculty in the mathematical sciences, the inclusion of minority students in REU programs is the best place to start.

5. Dennis Davenport: Recruiting Students from Underrepresented Groups

Because of the limited number of minorities who major in the mathematical sciences, one has to be persistent and creative when searching for qualified members

from underrepresented groups. Although generating applicants is important, it is also very important that a number of the applicants be qualified. A goal of most REUs is to encourage students to pursue advanced degrees in the mathematical sciences. A student who is unqualified this year may be qualified next year, given a year of mathematical training. There are several strategies one can use to recruit minorities from underrepresented groups.

We strongly suggest that you attend conferences which cater to minority students and faculty members, such as The National Association of Mathematicians (NAM) which is a non-profit professional organization whose main objective is the promotion of the mathematical development of underrepresented American minorities. Started in 1969, NAM aims to address the shortage of underrepresented minorities in the mathematical sciences by operating several educational and research programs, including NAM's MathFest. The goal of NAM's MathFest is to give guidance to minority undergraduate mathematical science majors and to introduce them to mathematical concepts they may not see at their home institution. They are also given the chance to give oral presentations to an audience of mathematicians and fellow mathematics majors. Visibility at MathFest can be enhanced by sending a student from your program to give a presentation and publishing an article about your program in NAM's fall newsletter, which is usually handed out during MathFest. This exposure has been a tremendous asset for some who have tried this strategy. Also the faculty members at minority serving institutions will find out about your program at MathFest. Surveys given by some programs have shown that as high as 78% of the students heard about them from a professor. Hence, we believe it is very important to reach as many faculty members as possible and NAM is an excellent vehicle to do so. There are similar conferences where these strategies have been tried and have shown some success, for example the Society for the Advancement of Chicanos and Native Americans in Science (SACNAS). Although this conference is for all sciences, there is a mathematical science component. There is also an undergraduate student poster session. Another excellent conference to try these strategies is the SIDIM Conference in Puerto Rico. This annual conference is held in late February, an excellent time to leave the frigid north for some sun. While this may pose some problems with the application deadline (most REUs have March 1 or earlier as deadline), this can be overcome by allowing students from the island a week grace period.

To reach faculty members we suggest doing a mass mailing, both through email and snail mail. There is a website (http://www.diverseeducation.com/index.asp) which gives the top fifty colleges for graduating minority students in any discipline. Make sure the institutions that graduate the highest number of members from underrepresented groups in the mathematical sciences are on your mailing list. Also include minority serving institutions and institutions with a large enrollment of minority students. Do not rely on the chairperson at these institutions to relay your information to interested faculty members or students. While the chairperson should be on your contact list, also include other faculty members at the institutions. Try to find faculty members who are interested in diversity issues. This can be done by calling the department or by searching the institutions website.

Also try contacting institutions that are involved in NSF's Louis Stokes Alliance for Minority Participation (LSAMP) program. Alliance members work diligently to increase the number of minorities from underrepresented groups in mathematics,

science, engineering and technology. A list of Alliances can be found at the following site: http://www.ehr.nsf.gov/EHR/HRD/amp.asp. Send a message to NSF's lead program director of LSAMP, Dr. A. James Hicks (ahicks@nsf.gov), letting him know about your program and commitment to recruit students from underrepresented groups. He will send a message to all alliances.

Today's students are very technology oriented. If you survey your students you will find that a large number of students are learning about your program through your website. For some programs this number has been increasing from year to year. A good webpage is essential to recruiting; it's inexpensive and easy to access.

Recruiting minority students is difficult, but doable. One must be persistent and creative. You may also want to take a chance on a student with good grades (not very good to excellent like most REU students) who has other positive qualities. Your decision could enhance the student's chances of success and provide the mathematics community with a capable graduate student.

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