# Promoting Diversity at the Graduate Level in Mathematics

*Proceedings of a National Forum*

October 14 – 17, 2008

Mathematical Sciences Research Institute

Berkeley, California (USA)

# Contents



# Promoting Diversity at the Graduate Level in Mathematics

**PROCEEDINGS OF A NATIONAL FORUM**

**HELD AT THE MATHEMATICAL SCIENCES RESEARCH INSTITUTE BERKELEY, CA (USA), OCTOBER 15 – 17, 2008**


**FUNDED BY**

**THE NATIONAL SCIENCE FOUNDATION**
**THE NATIONAL SECURITY AGENCY**
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Edited by Ellen E. Kirkman and Olivia A. Scriven, this report was prepared and based largely on the proceedings of a three-day forum entitled "Promoting Diversity at the Graduate Level in Mathematics." The report integrates data, presentations, and observations from the forum, while combining additional data and information addressing the issues of diversity and inclusion more broadly, and more specifically, efforts to increase the recruitment, retention, and graduation rates of women and other historically underrepresented groups in graduate programs in the mathematical sciences.

*Promoting Diversity at the Graduate Level in Mathematics • Proceedings of a National Forum*

Editors: Ellen E. Kirkman, Wake Forest University • Olivia A. Scriven, Partners for Educational Development, Inc.

## Forum Organizing Committee



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**On the cover:** *Top*—attending "A Diversity of Careers in Mathematics," Emille Davie, University of California, Santa Barbara and Laura DeMarco, University of Illinois at Chicago. *Center*—Sylvia T. Bozman, and to her right, Dusa McDuff, join conference attendees at Joshua Aronson's presentation. *Bottom*—the camera catches Chandra Erdman, graduate student, Yale University.

# A Call to Action

**THE *PROMOTING DIVERSITY* FORUM** was a call to action, a challenge, and an appeal to universities across the U.S., especially those at the forefront in producing the next generation of mathematicians, to address the issue of diversity in their graduate mathematics departments. It was also an opportunity for colleges and universities to explore the academic and non-academic barriers to success in U.S. graduate mathematics programs.

In recent years, several scientific communities have held conferences devoted to improving diversity, gender equity, and broadened participation of historically underrepresented groups. In its recent document "Broadening Participation at the National Science Foundation: A Framework for Action," the National Science Foundation (NSF) stresses the inclusion of underrepresented groups as the basis of expanded efforts to increase participation in all of its programs and activities. Consistent with those values and that commitment, the conference "Promoting Diversity at the Graduate Level in Mathematics: A National Forum" was a timely response to concerns of national urgency.

As lifelong professors at small women's liberal arts colleges (Spelman, a historically black college, and Bryn Mawr), we were not obvious candidates to lead an effort of this magnitude, particularly one that attempted to engage the broader mathematics research community in an examination of graduate education. We were, in the best sense, shepherded into this role by several well-meaning individuals. As diversity has been at the core of our professional partnership for nearly twenty years, we humbly attempted to rise to this formidable challenge.

The goal of this three-day conference was to stimulate, identify, and disseminate successful models that improve retention of underrepresented groups in graduate programs in mathematics. The forum provided an opportunity for the interchange of information among the key constituencies involved in graduate education: representatives from research universities, comprehensive universities, and small colleges, including graduate students. The conference afforded the 120 participants, 30 percent of whom

Sylvia T. Bozeman, professor of mathematics at Spelman College, and Rhonda J. Hughes, Helen Herrmann Professor of Mathematics at Bryn Mawr College, have partnered in the mathematical development of women and students from underrepresented groups for more than 15 years. In 1998 they founded and now serve as co-directors of Enhancing Diversity in Graduate Education (EDGE), a transition program for women that has been funded by the National Science Foundation, the Andrew W. Mellon Foundation, and the National Security Agency at various stages.

## EDGE

The Enhancing Diversity in Graduate Education (EDGE) program* was established in 1998 by Sylvia T. Bozeman (Spelman College) and Rhonda J. Hughes (Bryn Mawr College) to assist women students in successfully completing graduate programs in the mathematical sciences. EDGE is based on the premise that students who have demonstrated mathematical ability but have limited exposure to advanced mathematics courses can successfully earn PhDs in mathematics when provided with an introduction to advanced mathematical topics, an understanding of graduate school culture and a supportive community of mathematics faculty and student mentors. As of 2008, a total of 119 women have participated in EDGE, about one-half of whom are from underrepresented groups. Currently 18 EDGE alumnae have received PhDs in mathematics. Others have earned master's degrees, and many more EDGE alumnae are in the graduate school pipeline. Recently, EDGE formed regional mentoring clusters that address the need for continued mentoring of advanced graduate students, postdocs, and junior faculty.

The cornerstone of the EDGE program is its summer session, open to women who are about to enter a mathematical sciences graduate program or who are first-year

**Attendee Katrina Hardin-Williams, Spelman College**

were graduate students, an opportunity to improve the articulation between undergraduate and graduate training in order to develop strategies to improve retention of students from these institutions. Department representatives were encouraged to leave the conference with an appropriate plan for action. In planning the conference, the Forum Organizing Committee looked for new ways to illuminate barriers to diversity that exist in graduate programs and attempts being made to overcome those barriers. The committee also looked for ways to develop new ideas and disseminate strategies of programs and advisors that have been effective in producing PhDs among women and other underrepresented groups. In addition, the forum recognized the mathematical achievements of women and minority mathematicians, and provided networking opportunities for students and faculty.

Perhaps the most unique element of the forum was the opportunity provided for faculty to hear the voices of current and former graduate students, in their own words, both through those present at the conference and through anonymous stories submitted for reading by faculty. The forum was also unique in its formal and informal exchanges and networking between faculty and graduate students from different types of institutions, who contemplated barriers and solutions for achieving diversity while illustrating diversity at work. We hope that this forum will inspire those at individual, departmental, and institutional levels to develop and implement strategies that facilitate change, broaden participation, and move toward a more inclusive mathematics community.

**" It is our hope that this conference will inspire those at individual, departmental, and institutional levels to develop and implement strategies that facilitate change, broaden participation and move toward a more inclusive mathematics community."** — Rhonda Hughes

To achieve these goals, we depended on the expertise and commitment of our distinguished Forum Organizing Committee, the contributions of forum attendees in moderating and serving on panels, and the professionalism of the staff of the Mathematical Sciences Research Institute (MSRI) and the EDGE program. Lloyd Douglas, Deborah Lockhart, and Peter March at the NSF urged us to expand our original vision for this conference to the one that ultimately took shape. Michelle Wagner at NSA and Danielle Carr, formerly of the Mellon Foundation, have been strong supporters of our work over the

years, and of this conference in particular. It was the full Organizing Committee that gave shape and form to early ideas and nurtured their growth. Duane Cooper, Morehouse College, and Abbe Herzig, SUNY-Albany, gave untiring attention to program details, and worked with us at every stage of development. We benefitted immeasurably from the experience and advice of additional committee members Fern Hunt, National Institute of Standards and Technology (NIST), Dusa McDuff, Barnard College, Ivelisse Rubio, University of Puerto Rico, and Karen Uhlenbeck, University of Texas, Austin. We owe a great debt of gratitude to committee members Ellen Kirkman, Wake Forest University, and Olivia A. Scriven, Partners for Educational Development, Inc., who gave leadership to the planning of these proceedings, authored them, and presented clearly and engagingly the essence of the conference, and to Liana King, for design and layout of the document. We warmly thank them all.

It is our intention that these proceedings will serve as a resource for faculty and departments engaged in the challenge of diversifying their programs. In addition, it should provide a useful guide to data and data sources as well as to recommendations from a community that embraces the value of diversity. You will find here a compilation of recommendations from departments that are at various stages in revisiting and revising their own graduate program structures. For those who seek to create new structures or revise policies and practices in their graduate programs, we hope that the voices and recommendations of the graduate students and faculty here will both encourage you and provide you with ideas for adaptation and implementation. We would be pleased if this document fortifies you with support in your own efforts to improve diversity and to recognize the value of supporting all graduate students in ways that help them to fully develop their individual potential and empowers each to grow, flourish, and become, in the words of Hyman Bass, "stewards of the discipline."

We extend our deep appreciation to David Eisenbud and Hugo Rossi, past director and associate director of MSRI, who originally offered the facilities and helped to identify the funding for this conference, and to current director and associate director Robert Bryant and Kathleen O'Hara, who welcomed and supported the conference with superb professionalism, extraordinary sensitivity, and outstanding staff support. We also owe thanks to many MSRI staffers, particularly Jonathan Rubinsky, and to EDGE program coordinator Linda Pace, for the orderly flow of conference activities and the collection of materials for the preparation of these proceedings.

— Sylvia T. Bozeman and Rhonda J. Hughes

graduate students. The summer session consists of two core courses in analysis and algebra/linear algebra, mini-courses in areas of mathematical research, short-term visitors from academia and industry, guest lectures, and problem sessions conducted by graduate student mentors.

The staff introduces and helps students to anticipate the graduate school culture. In addition, a follow-up mentoring program and support network is established. The success of the EDGE program is reflected in its high graduate student retention rate. A priority is reflected in its commitment to the creation of a diverse mathematics community. The EDGE program received an AMS award for "Mathematics Programs That Make a Difference" in 2007.**

* www.edgeforwomen.org/

** www.ams.org/ams/press/coprof-programs-2007.html)

Find articles about EDGE at: www.edgeforwomen.org/?page_id=12.

**"The forum provided an opportunity for the interchange of information among the key constituencies involved in graduate education: representatives from research universities, comprehensive universities, and small colleges, including graduate students."**

— Sylvia T. Bozeman

# Framing the Issues:

## MTBI/SUMS

MTBI/SUMS resulted from the 2004 merger of the Mathematical Theoretical Biology Institute (MTBI) and the Institute for Strengthening Understanding of Mathematics and Science (SUMS). MTBI was started by Carlos Castillo-Chavez of Arizona State University and SUMS was created by the late Joaquin Bustoz, Jr. Since 1996, MTBI/SUMS has offered research experiences for undergraduate and graduate students in applications of mathematics and statistics to questions in the biological and social sciences. The program has mentored and supported 277 undergraduate and 31 graduate students, and most of the participants in MTBI/SUMS have been members of underrepresented minority groups or women. MTBI/SUMS participants have coauthored 111 technical reports since the program's inception.

MTBI/SUMS summer programs are designed to function as a research workshop. New students take three and a half weeks of intense training in dynamical systems and modeling in the biological and social sciences. The students set the research agenda, forming groups of three or four to work on projects of their own choosing, with the advice of a faculty mentor.

In its first ten years of existence, MTBI/SUMS sent 169 students to graduate school (including 130 minority students). In 2005, ten MTBI/SUMS alumni (seven from minority groups) received PhDs in the mathematical sciences.

**"To maintain its scientific and engineering leadership amid increasing economic and educational globalization, the United States must aggressively pursue the innovative capacity of *all* of its people."**

***— Beyond Bias and Barriers*, 2007**[1]

**THE TERM 'DIVERSITY'** has pervaded the national discourse in recent years. It is of particular concern in the science, technology, engineering, and mathematics (STEM) community. With studies increasingly showing the link between national economic prosperity and security and the research and technology enterprise, the call for greater investments in the education of scientists and engineers has reached new heights and intensity. Colleges and universities, it is argued, are central to the growth process but have been falling short in nurturing the diverse body of talent who can engage in critical research and development activities to move the economy forward.

At the graduate level, where students inch closer to becoming recognized members of the STEM community, research shows that less than 50 percent of new PhDs in the mathematical sciences have been awarded to U.S. citizens each year since 1987-8 (Table 4: 1987 Survey First Report, p. 1084). The data is even more striking when it comes to racial and ethnic minorities and women—groups that historically have been and continue to be disproportionately underrepresented in STEM but by sheer numbers provide a growing source of potential and talent.[2] In 2005, a total of 541 PhDs were awarded in mathematics and statistics to U.S. citizens and permanent residents. Of this number, 28 percent [N=151] were conferred on women and a combined 8 percent [N=46] were conferred on African Americans and Hispanics/Latinos. None were awarded to Native Americans/Alaskan Natives.[3]

**But what, exactly, is meant by the term diversity?** Why are racial and ethnic minorities and women persistently underrepresented in STEM, and what can be done by colleges and universities at individual, departmental, and institutional levels to increase rates of participation, advancement and graduate degree production? The 2008 *Promoting Diversity* Forum provided a platform for the interchange of information among a variety of stakeholders —researchers, scholars, and educators from the mathematical sciences community, public policy officials, and most importantly, students —to address these issues and develop recommendations for action.

# The Case for Diversity

Shirley Malcom, head of the Directorate for Education and Human Resources Programs of the American Association for the Advancement of Science (AAAS).

Shirley Malcom, head of the Directorate for Education and Human Resources Programs of the American Association for the Advancement of Science (AAAS), helped to place the issue of diversity in both a contemporary and historical context. Having committed most of her professional career to public policy research on the topic, Malcom noted that the underrepresentation of certain groups in STEM is not new but argued that the lack of substantive progress after more than 40 years of effort represents a structural impediment to inclusion. "The culture of graduate programs is that you need permission to join," Malcom told the audience. An early African American female pioneer in the sciences who earned her doctoral degree in ecology from Pennsylvania State University when role models were few, Malcom went on to note that, "It's hard to imagine yourself in a place where no one else looks like you. It feels like you are waiting for permission to join. You feel like you need a special invitation." The impact of these structural impediments to inclusion is represented in the data, which Malcom asked the audience to consider in this way, "There is a pathway through the sciences, through the education system. At each stage of the pathway, we're losing critical talent."

The National Science Foundation (NSF), a major sponsor of the forum, understands the magnitude of the issue of diversity and its future implication if not addressed in a manner that is agency-wide and systemic. Deborah Lockhart, Executive Officer in the Division of Mathematical Sciences at the NSF, works with a variety of other program

Those seven PhDs account for one-quarter of all PhDs awarded that year to U.S. citizens who are members of minority groups. Also in 2005, 15 women who are members of underrepresented minorities received PhDs in mathematics and five of them are MTBI/SUMS alumnae. MTBI/SUMS is thus having a major impact on the number of advanced degrees being awarded to members of underrepresented minorities. Overall, 24 MTBI/SUMS alumni have received PhDs in the mathematical sciences.

The MTBI/SUMS program received an AMS award for "Mathematics Programs That Make a Difference" in 2007: www.ams.org/ams/press/coprof-programs-2007.html

Find more information at: http://mtbi.asu.edu/.

**"There is a pathway through the sciences, through the education system. At each stage of the pathway, we're losing critical talent." — Shirley Malcom**


**The Faculty Respond panel, from left: Ismar Volic and Stanley Chang, Wellesley College; Estela Gavosto, University of Kansas; Cora Sadosky, Howard University; Amy Cohen, Rutgers University; Bob Megginson, University of Michigan and deputy director of MSRI; and Don Cole, The University of Mississippi.**

## TRACHETTE JACKSON

Trachette Jackson is a Professor of Mathematics at the University of Michigan. She is an applied mathematician who works in mathematical biology, currently on cancer biology.*

As a high school student, Trachette wanted to become an astronaut, but the Math-Science Honors Program (MSHP), a summer program for high school students at Arizona State University, sparked her interest in applied mathematics. In the summer MSHP program, she took calculus with other students who looked like her and had similar goals. She still corresponds with many of these students. ASU Professor Joaquin Bustoz, Jr. (see sidebar on MTBI/SUMS, page 6) talked to Trachette and her parents and convinced them that ASU was the best place for Trachette to attend college. Trachette's goal was to major in engineering, but a second conversation with Professor Bustoz convinced her to try mathematics, and she participated in the SUMS program. In the summer program she heard a talk, "How the Leopard Got His Spots," by James D. Murray of the University of Washington; the talk was about using mathematics to solve problems in the biological sciences. She knew then that this was the sort of mathematics that she wanted to do, but she needed more training in the biological sciences. She participated in the Minority Access to Research Careers (MARC) program — an NIH program in the late 1980s to train underrepresented

**When she completed her degree, she realized that her education was not completed; her degree was 'a ticket to learn.'**

directorates and special initiatives at the organization to broaden participation. Lockhart explained that the NSF defines broadening participation as including individuals from underrepresented groups — as well as institutions and geographic areas that do not participate in NSF research and the review process — at rates comparable to others.[4] For the purposes of this document, underrepresented racial and minority groups are limited to African Americans, Hispanic Americans, and Native Americans.**

Michelle Wagner, Director of the Mathematical Sciences Program at the National Security Agency (NSA), another sponsor, sent a message pointing to the importance of the conference based on her own personal experiences pursuing a graduate degree in mathematics at Emory University in Atlanta, Georgia. Wagner reflected that, "it is very unlikely that I would be where I am today if not for the deliberate influence of supportive and aware professors from my undergraduate career and a fellowship targeted towards women that put me through my PhD program." The NSA also recognizes the role of government in implementing programs to continue to inspire and support the development of talent. For the NSA, this support is basically accomplished through grants for research and conferences in the mathematical sciences. Wagner noted that "by supporting the research of professors and the development of their students, the hope is that we elevate the overall quality and capabilities of the mathematical sciences community."

While the rates of participation in graduate programs in the mathematical sciences by the target groups are undeniably low, the *Promoting Diversity* forum showcased programs that work. Told through the personal and professional experiences of faculty, administrators, and students, the forum helped to give greater visibility and voice to women and mathematicians from traditionally underrepresented groups who have persisted to the doctoral degree, laying bare challenges and triumphs along the way. Many of the challenges have been identified before. But these challenges took on new meaning and importance when told through first-person narrative — subtle and often explicit biases; organizational structures and policies that prohibit inclusion, creativity, and pathways of growth; a "sink or swim" philosophy to graduate education; and isolation.

**Forum attendees Deanna Haunsperger, left, and Steven Kennedy, seated, mingle with others at a break between sessions.**

Empowered to act, participants convened in breakout groups and emerged with a series of recommendations and adaptable strategies to improve campus climates and increase student recruitment and degree-production rates. These recommendations included new pedagogical paradigms and approaches—apprenticeships, mentoring, transparent criteria, supportive leadership, participation in study and support groups, and individual acts of advocacy and program survival. As we will see in the pages that follow, women and racial and ethnic minorities have succeeded, and more can succeed, when their talent is recognized and concerted effort is made by a broad community to continue to support and help advance their professional development.[5]

**ENDNOTES**

1. Committee on Science, Engineering and Public Policy, National Academy of Sciences, *Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering*, Washington, D.C.: National Academies Press (2006).
2. According to the U.S. Census Bureau, minorities, now roughly one-third of the U.S. population, are expected to become the majority in 2042, with the nation projected to be 54 percent minority in 2050. By 2023, minorities will comprise more than half of all children. [See www.census.gov/Press-Release/www/releases/archives/population/012496.html Accessed: 02Jan2008]
3. National Science Foundation, Division of Science Resources Statistics, Women, Minorities and Persons with Disabilities: 2007 (NSF 07-315) [TABLE F-11. S&E PhDs awarded to U.S. citizens and permanent residents, by field, sex, and race/ethnicity: 1998–2005].
4. The U.S. Census Bureau defines ethnic and racial minority groups as African Americans, Hispanic, Native American (which includes Alaskan Natives and American Indians), Asian American, and Pacific Islanders. In this document, the term 'underrepresented' refers to racial and ethnic minority groups which the NSF identify as pursuing and earning degrees in science disciplines disproportionate to their numbers in the U.S. population. The groups include African Americans, Hispanic Americans and Native Americans.
5. The term 'underrepresented minorities' refers to those groups which the NSF identify as pursuing and earning degrees in science disciplines disproportionate to their numbers in the U.S. population. The groups include African Americans, Hispanics/Latinos, Native Americans and Alaskan Natives.

** www.nsf.gov/od/broadeningparticipation/framework_report.jsp

minorities in biomedicine; the program was broadly defined and mathematics was a part of biomedical research. ASU was a very nurturing undergraduate environment. She graduated from ASU with confidence in her ability and a desire to persevere. She began graduate studies in applied mathematics at the University of Washington, but she soon found that she was not as well prepared as the other students . Her confidence was shattered, and she began to feel that she could not succeed. She remembered the words of Virgil: "They can because they think they can." She decided," There is no failure except in no longer trying," and worked hard to catch up. She wrote her doctoral thesis under James D. Murray, the professor who gave a talk one summer at ASU, and the rest is history! Her thesis involved work with Dr. Peter Senter of Seattle Genetics. Once she completed her degree, she realized that her education was not completed; her degree was "a ticket to learn." She completed several postdoctoral fellowships before beginning her career at Michigan, where she is helping to mentor others. She quotes Marian Edelman Wright, "We must not, in trying to think about how we can make a big difference, ignore the small daily differences we can make which, over time, add up to big differences that we often cannot foresee." Jackson advises students to be determined. "YOU are in control. If you are willing to work hard and to surround yourself with positive people, you will succeed."

An interesting postscript is that six of the seven students in her entering graduate class at the University of Washington did complete the doctoral degree.

* www.math.lsa.umich.edu/people/facultyDetail.php?uniqname=tjacks

# Exploring the Data:

THERE NOW EXISTS AN abundance of sources that track undergraduate and graduate degree production and attainment across all types of institutions and by women and underrepresented minorities in the mathematical sciences. During a presentation entitled "What the Data Show and What We Know About Diversity in the Mathematics Community," Ellen Kirkman, professor of mathematics at Wake Forest University, examined many of these data sources. The NSF provides one of the best starting points to gain a broad picture of enrollment and degree production via its Congressionally-mandated report *Women, Minorities and Persons with Disabilities in S&E*. The report presents trends in the participation of women, minorities, and persons with disabilities in science and engineering, with topics ranging from higher-education enrollment and top-degree producing institutions to employment status and occupations. The report (along with links to further data) is downloadable and available at the NSF web site. The magazine *Diverse* provides a wealth of data on underrepresented minorities, broken down by field and by year.*

**The NSF data for 1998-2005 also show little change in doctoral degrees granted to underrepresented minorities, U.S. citizens and permanent residents.**

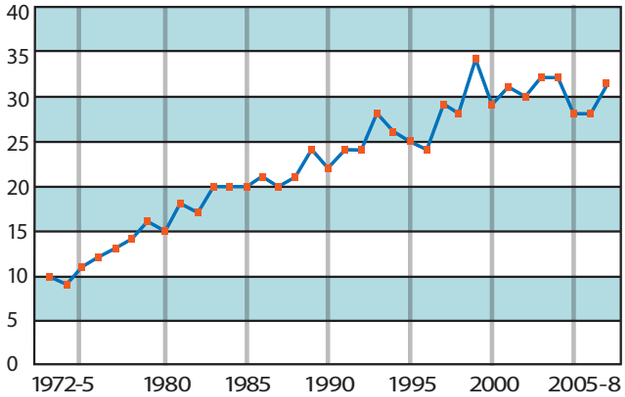
As we examine trends in the mathematical sciences more specifically, a variety of other data sources provide critical snapshots. Dr. Kirkman, along with several other panelists, reviewed several of these sources. For example, each year the Data Committee, a joint committee of many of the mathematical professional societies [American Mathematical Society, (AMS); American Statistical Association, (ASA); Institute of Mathematical Statistics, (IMS); Mathematical Association of America, (MAA); and the Society for Industrial and Applied Mathematics, (SIAM)] surveys all the mathematical sciences departments that award doctoral and master's degrees and a random sample of departments offering only undergraduate mathematical sciences degrees. Three reports based on this data are published each year in the *Notices of the AMS*.** These reports include data on new PhDs, faculty, undergraduate and graduate students. Some of the data is broken down by gender, race/ethnicity or type of institution.

A report on the participation by women in the AMS is published each year in the *Notices of the AMS* (the most recent such report is in Vol. 55 No. 9 (2008) p. 1132). Every five years, the Conference Board of the Mathematical Sciences (CBMS) sponsors a survey of a stratified random sample of departments offering undergraduate majors in mathematical sciences. These reports contain considerable data on undergraduate faculty and enrollments.***

***According to the most recently available data, women comprise:*** ****

- about 45 percent of the bachelors degrees awarded in the mathematical sciences in 2005: Table 4C:
- 40 percent of the masters degrees awarded in the mathematical sciences in 2006-7: Table 5C, Third Report 2007
- 30 percent of full-time graduate students in mathematical sciences doctoral programs in 2006-7: Table 6B, Third Report 2007
- 31 percent of the new PhDs in the mathematical sciences awarded to U.S. citizens in 2006-7: Tables 3D and 3E, Second Report 2007, and
- 22 percent of the tenured/tenure-track mathematical sciences faculty in Fall 2007: Tables 1A and 1B, Third Report 2007.

***Figure 1:*** **Percentage of U.S. Women Awarded New Mathematics and Science Doctorates, 1972-2008**




*Source:* Annual Surveys of the Data Committee – *published in the* Notices of the AMS.

* www.diverseeducation.com
** www.ams.org/employment/surveyreports.html
*** www.ams.org/cbms/
**** www.nsf.gov/statistics/wmpd/degrees.cfm

# What We Know, What Is Still Unclear

## Mathematics Doctorates Awarded in 2005

| Race/Ethnicity and Sex | Year: 2005 |
|---|---|
| All U.S. Citizens and Permanent Residents | 541 |
| Female 151 Male 390 | |
| **White** | **413** |
| Female 106 Male 307 | |
| **Asian** | **66** |
| Female 28 Male 38 | |
| **Black** | **22** |
| Female 7 Male 15 | |
| **Hispanic** | **24** |
| Female 6 Male 18 | |
| **American Indian/Alaska Native** | **NONE** |
| Other/unknown race/ethnicity | 16 |
| Female 4 Male 12 | |

*Source*: *Women, Minorities & Persons with Disabilities*, 2007 (NSF 07-315)

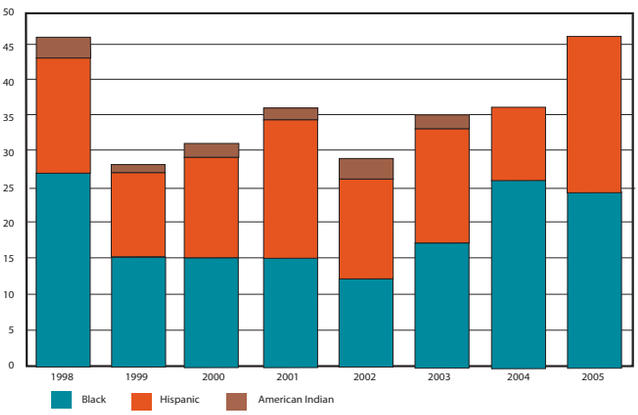
The data also show that the percentage of women obtaining PhDs in the mathematical sciences has been slowly increasing: e.g. the percentage of women among new PhDs in the mathematical sciences given to U.S. citizens has risen from 11 percent in 1974-5 ("Annual Survey, Part 1," 1975 p. 308) to 31 percent in 2006-7 *(Figure 1)*. While overall percentages have been increasing, the data reveal patterns of attrition among women, more broadly, at each successive stage in the educational pipeline. However, the percentages of women graduate students and the percentage of women among first year graduate students have remained relatively stable over the last 10 years: Table 6B, Third Report 2007.

When the data is disaggregated for race and gender, the paucity of degree attainment is more apparent and acute. As reflected in the table above, while women earned 28 percent [N=151] of mathematics PhDs in 2005, less than 3 percent [N= 13] were conferred upon women from underrepresented racial groups—African Americans, Hispanics, and American Indian/Alaska Natives.

There is another phenomenon that needs to be made clear. In evaluating data on the gender of new mathematical science PhD recipients, one should remember that when degrees in statistics are removed from the total, the percentage of women among new PhDs drops—for 2007 from 32 percent to 28 percent: Table 9, First Report 2007. Women faculty are still less common at doctoral institutions than at master's and baccalaureate-level institutions. For example, in 2007 women were 12 percent of the tenured and tenure-track faculty offering PhDs, and 27 percent of the tenured/tenure-track faculty at colleges and universities that offer only the bachelor's degree: Table 1E, Third Report 2007. There has been interest in determining the graduate schools that have been most successful in producing women PhDs in the mathematical sciences. See "Has the Women-in-Mathematics Problem Been Solved?" Allyn Jackson, *Notices of the AMS* August 2004.

The exclusion of ethnic/racial minorities (women and men) in the mathematical sciences at all stages of the higher education spectrum is even more dramatic than that among women. The First Report of the Data Committee presents the race/ethnicity of new PhDs in the mathematical sciences. For 2006-2007, the most recent year for which data is available, the 500 U.S. citizen new PhDs included 10 Blacks, 12 Hispanics or Latinos, and two American Indians or Alaska Natives: First Report 2007, Table 6. The number of new PhDs awarded to underrepresented minorities has not changed significantly. For example, in 1974-5, there were nine Blacks, five with Hispanic surnames, and one American Indian among the 741 new mathematical sciences PhDs (Annual Survey, Part 1, 1975, p. 308). The NSF data for 1998-2005 also show little change in doctoral degrees granted to underrepresented minorities U.S. citizens and permanent residents *(Figure 2)*.

***Figure 2:*** **Mathematical Science PhDs Awarded to Minority U.S. Citizens and Permanent Residents, 1998-2005**




*Source: www.nsf.gov/statistics/wmpd/degrees.cfm#doctoral*

# Personal Narratives: Giving Voice to

ONE OF THE BEST TOOLS to better understand why individuals stay in or opt out of the mathematical sciences is a first-person narrative. Leona Harris, assistant professor of mathematics at the College of New Jersey, and Rachelle DeCoste, assistant professor of mathematics at Wheaton College in Massachusetts, moderated a panel at the *Promoting Diversity* forum that enabled students at various stages in their graduate and professional careers to share their experiences in a way that facilitated a sense of empowerment that many felt was not available to them in their own graduate school journeys. Farrah Chandler from Elizabeth City State University in North Carolina, spoke of making the transition from an undergraduate to a graduate school environment and dealing with questions of academic readiness and fitting in, while Valerie Nelson, in the program at Morgan State University in Maryland, addressed the issue of balancing the demands of graduate school with the need to have and maintain a personal life. "When life happens," Nelson told the audience, "cry, grieve, take a break or do whatever is necessary to release, regroup, and refocus."

Other students, such as Alejandra Alvarado at Arizona State University, described the sink or swim nature of qualifying exams, while Luis Medina from Rutgers University spoke of being ready for life after graduate school. The options are numerous, from a postdoctoral position to immediate entry as a junior faculty in academia to positions in industry. The university, the department, and the faculty mentor should all play a role in helping a student to navigate opportunities that best fit her or his interests and skill sets.

**"When life happens," Nelson told the audience, "cry, grieve, take a break or do whatever is necessary to release, regroup and refocus."**

Overall, the panelists offered recommendations to make the graduate program environment more inclusive and one in which students feel a sense of personal empowerment to affect change. This includes the following:

**Increasing Awareness and Contact at the Undergraduate Level.** Efforts to recruit women and racial/ethnic minorities need to include interventions at the undergraduate level to increase student awareness of the different types of graduate programs and to assist in selecting programs that are a good match based on career interests, learning styles, and other key factors that might influence outcomes.

**Role Models and Sustained Support.** The panelists also suggested that diversity be a factor in selecting a department chair and that the presence or absence of women or underrepresented racial/ethnic minorities on the faculty sends a strong message about a department's acceptance of and support for future students from these underrepresented groups. Interestingly, the panelists agreed that while having role models in the department who share minority characteristics is important, such role models may not necessarily be the best advisors for underrepresented ,minority students. Rather, the panelists agreed that there needs to be a climate of open and honest dialogue with students when they need to improve their mathematical skills, and one in which this dialogue is matched with a program of tangible and sustained support. The panelists stressed that "if you are not planning to follow through and support the women/minorities you bring in, don't bother, or we feel abandoned." They further offered that it takes time to build a pipeline and a critical mass; departments must be patient and keep at it.

# Students and Recent Graduates

**Strong Leadership, Mentoring, Transparency, and Openness to Doing Things Differently.** Finally, the need for strong leadership, transparency, and an openness to creativity and alternative approaches were also echoed by the panelists. The idea of replicating past paradigms and approaches to graduate school training simply because that is how it was done in the past was a notion that the panelists agreed needed to be evaluated and assessed based on current circumstances. Institutionalized flexibility, they argued, is crucial to student recruitment and increased graduation rates. Departments were encouraged to consider several specific options: explore and implement non-traditional ways of taking courses, such as consortia arrangements and articulation agreements between small and larger institutions that would support cross-registration to broaden the variety of courses; give real prerequisites and a concrete statement of what a student is expected to know and options on how to fill gaps; communicate the value of mentoring, train faculty how to mentor and reward mentoring as service.

During a similar panel, Dusa McDuff, the Helen Lyttle Kimmel '42 Professor of Mathematics at Barnard College in New York, and Teresa Edwards, associate professor of mathematics at Georgia Gwinnett College in Atlanta, helped the audience to understand the impact individual actions and institutional policies can have on persistence. Members of the faculty panel read short essays that were submitted by graduate students who had recently completed doctoral degrees in mathematics or chose not to pursue a degree beyond the master's.

**On the Issue of Combining Family with Graduate School.** One student wrote that when she made the choice to start a family, faculty and other graduate students changed the way they interacted with her. Several individuals overtly questioned the student's seriousness in becoming a mathematician, as though motherhood and math were diametrical opposites. But to some, there was no middle ground, no accommodating a dual identity. It was an either-or situation. In her anonymous essay, the student recalled one faculty member who told her that "mathematicians required a singularity of focus that mothers could not accommodate." When she tried to negotiate a maternity leave, the faculty member informed her that graduate students were not eligible for maternity leave. Surprised by the policy, the student discovered that if she exercised her only other option, a medical leave, she would lose her highly sought-after graduate housing, which had taken two years on a waiting list to secure. The more she

**Several individuals overtly questioned the student's seriousness in becoming a mathematician, as though motherhood and math were diametrical opposites.**

Chandra Erdman, graduate student, Yale University.

researched, the more the student had to come to terms with the reality of her situation, a reality of institutional policies and individual attitudes that simply did not support being pregnant and being in a graduate program in mathematics. Her anxiety was complicated by the added burden of feeling as though her success or failure would influence attitudes toward and assumptions about future female students. It was a legacy she did not relish, so the student pressed on, returning to the program a week after giving birth. Ten months later, she earned her doctoral degree.

For several other students whose essays were read during the panel, the struggles were equally compelling but the endings less happy. Passing the analysis qualifying exam

**"Being targeted by well-known cultural stereotypes ('girls can't do math') can be very threatening, a predicament my mentor and I called 'Stereotype Threat.'"**

— Joshua Aronson
The Steinhardt School, New York University

was the only thing that stood between one student and her moving to the next stage of her graduate program. When she failed the exam for the second time, she met with her professor to review the results. The professor was unable to explain why the points were deducted and would not allow the student to make a copy of the exam or to negotiate the two points needed to get a passing score. At the end, he just said, "I'm not sure." That was it. When the student met with the chair of the department to review her status in the program, she was told, "you can go somewhere else and be a star."

**On right, Estela Gavosto, University of Kansas.**

While every panelist's experience was unique, common themes and challenges emerged that are also reflected in the literature. One problem common to U.S. graduate students—irrespective of race and gender—is that of competing with graduate students from abroad, who experience a more technical undergraduate education and are often not required to teach when they enter graduate programs. This results in more time to devote to coursework, exams, and research than students who are also facing the new task of becoming teachers.

It was also noted that students from smaller colleges and universities tend to have less exposure to more advanced mathematical sciences courses. Sometimes when they begin graduate studies these students are pushed into upper-level courses for which they are not fully prepared. Many students who decide to do graduate work in the mathematical sciences leave a small, undergraduate institution where they were each a "star" —where faculty have successfully built their confidence to succeed in mathematics —only to encounter difficulties in their graduate courses where faculty may be less accessible, less nurturing and the environment more competitive and intensive, a situation many of these students had not experienced before.

Women and underrepresented minority graduate students alike report many additional problems that they have encountered in graduate programs in the mathematical sciences. Some graduate programs have

**From left, Mary Gray, Professor of Mathematics and Statistics at American University and the first president of the Association for Women in Mathematics(AWM), and Cora Sadosky, Professor of Mathematics at Howard University and eleventh president of the AWS, taking a break between sessions.**

policies that allow a graduate student a maternity leave, while many programs make no such allowances. Some graduate students in the mathematical sciences programs have encountered sexist or racist attitudes among the faculty, graduate students, or the students they were teaching. Sometimes this prejudice takes the form of the assumption that the student is not qualified or will not succeed. Students who are racial or ethnic minorities often find it difficult to be invited into study groups or learn the unwritten rules of how the graduate program operates —who writes the preliminary exams, where you get copies of copies of old exams, etc. Underrepresented minorities still face the additional pressure of feeling that they are representing all minorities. They feel they must prove they belong. They feel exposed in ways other students do not.

**Garikai Campbell, associate professor of mathematics and statistics and associate dean for academic affairs at Swarthmore College, participates in a panel discussion along with Emille Davie, Laura DeMarco, Alina Cojocaru, and, to Dr. Campbell's left, Beatrice Riviere.**

**"I want to be perceived as a mathematician."**

— Alina Cojocaru, University of Illinois, Chicago
*(pictured above)*

**Alina Cojocaru** is Assistant Professor of Mathematics, Statistics and Computer Science at the University of Illinois, Chicago, (UIC) and recipient of the prestigious NSF Career Award. Cojocaru's journey to earn the doctoral degree in mathematics took her across three continents and four countries. As a child growing up in Romania, she liked mathematics, and her parents encouraged her interests through participation in mathematics camps and enrollment in a high school for science and mathematics. However, if she stayed in Romania, her only option would have been to teach; doctoral studies were not an option. Cojocaru made the difficult decision to leave the familiarity of home, traveling first to Italy to continue her studies and later to Canada. It was not until she entered a program at Princeton University that she was ever confronted with being female and a mathematician. For Cojocaru, the gender component was not something about which she had ever really given much thought. Yet, she felt the distinctions made between her and her male colleagues would prove problematic for her. Cojocaru, who is on a tenure track at UIC, said, "I want to be perceived as a mathematician."

**"Words have an impact."**

— Garikai Campbell, Swarthmore College
*(pictured above)*

**Garikai Campbell,** associate professor of mathematics and statistics and associate dean for Academic Affairs at Swarthmore College, a private liberal arts institution in Pennsylvania, told of his last year of undergraduate school. He had not done well in a particular class, and one professor asked him to reconsider his goals of attending Rutgers University and consider a less intensive, less competitive graduate program. For the well-intentioned faculty member, the conversation was probably fairly innocuous. For Garikai, who came from a family of high-achieving academicians and from an early age set the goal of obtaining the doctoral degree in mathematics, the conversation was near devastating. Campbell ultimately was able to move beyond that moment, enter Rutgers University and earn his doctoral degree and is now working to create an environment at Swarthmore where students can thrive. But reflecting back on that experience, Campbell asked the audience to consider that "words have an impact."

# Critical Transitions: Navigating the Gaps

The transition from an undergraduate to graduate program in mathematics is a critical point where talent can be lost if care is not taken to close the gap.

The *Promoting Diversity* forum gave a face and voice to the growing body of research in this area. Trachette Jackson, professor in the Department of Mathematics at the University of Michigan, Ann Arbor, shared her personal journey as an African American female mathematician. Though she had excelled in the field during most of her academic journey, the transition from an environment in which she was considered a 'star' undergraduate at Arizona State University to the more intensive and demanding environment at the University of Washington proved a challenge that tested her resolve and nearly shattered her confidence. But it was a life-defining moment of instability that Jackson would ultimately overcome. For Jackson, in addition to academic skill and personal desire, "being successful in the mathematical sciences takes 20 percent nature, 60 percent nurture, and 100 percent determination."

"A Diversity of Careers in Mathematics," Emille Davie, University of California, Santa Barbara and Laura DeMarco, University of Illinois at Chicago.

## Bridges of Dialogue Between Expectation and Reality

To better support students who come to doctoral programs from non-doctoral and/or liberal arts institutions, PhD-granting institutions need to understand the culture of the non-doctoral institutions, so that they can develop the talent of students who come from what can be a very different culture. Duane Cooper, associate professor of mathematics at Morehouse College, an historically black, liberal arts college for men in Atlanta, moderated a panel that explored these varied "institutional cultures"—from the small liberal arts and women's colleges, to the broad spectrum of minority-serving institutions to major research universities.

Leona Harris, The College of New Jersey and Rachelle DeCoste, Wheaton College, moderate the panel "The Students' Perspective—Navigating through Critical Transition Points."


For students, as well as faculty, there is often a gap between expectation and reality that can result in disappointment and disillusionment, and ultimately, the decision to opt out. For Janis Oldham, associate professor of mathematics at North Carolina A&T State University (NCAT), the challenge is not only situated in creating an environment to engage and support students but the challenge is also in understanding the culture of the institution itself. As one of 105 historically black colleges and universities (HBCUs) spread across 17 states and the U.S. Virgin Islands,

# Between Undergraduate and Graduate Cultures

A moment of relaxed conversation for attendees, from left to right, Farrah Jackson, Beth Campbell-Hetrick, and Valerie Nelson.

NCAT was originally established as a separate institution to provide technically-oriented education for African Americans. Now, as one of the leading producers of African American engineers, NCAT is classified as a comprehensive, research-intensive institution that serves a diverse student body. Oldham explains that "this change in classification and course offerings has also had an impact on the teaching and learning environment."

**"In addition to academic skill and personal desire, being successful in the mathematical sciences takes 20 percent nature, 60 percent nurture, and 100 percent determination."**

—Trachette Jackson

Yi Li, professor and chair of mathematics at the University of Iowa, a public research university enrolling an average of 29,000 students and 1,700 faculty, explained that change to increase retention and graduation rates has been a 10-year effort. The process included an intentional effort to shift from a philosophy of "sink or swim" to one where students could succeed. The university enhanced its infrastructure to enable the assignment of mentors to all incoming students. Further changes included waiting until a student had passed her/his qualifying exam before being assigned as a teaching assistant. At the University of California, San Diego (UCSD), also a state-supported university, Jim Lin, vice chair of graduate studies, has witnessed what he characterizes as growing pains. Between the period 2000 through 2007, the university's student population increased from 18,500 to 28,500 and the number of PhD students in mathematics increased from 84 to 114. With growth came the need to increase the structures to support students, especially underrepresented minorities and women, most

## THE UNIVERSITY OF IOWA

BUILDING COMMUNITY
IN THE HEARTLAND

The University of Iowa began its commitment to the graduate education of students from underrepresented groups in 1995, and it has become a national leader, despite its local demographics. Underrepresented minorities accounted for 20 to 25 percent of its graduate student population over the period 2000-05. Over the past decade, the University of Iowa has produced about 1 percent of total PhDs and 4 percent of those awarded to underrepresented minorities. Doctoral degrees were awarded to four minority students in 2007 and to two minority students in 2008.

The department has designed a carefully orchestrated recruitment plan that includes partnerships with several HBCUs and Latino institutions; this partnership involves about 50 undergraduate faculty from minority serving institutions. The university has a carefully designed program to help graduate students succeed. The program begins with an intensive summer institute, weekly help session, and intensive faculty and student mentoring. The program has been institutionalized, and has survived several changes in leadership. The program has won several awards: 2004 Presidential Award, 2006 AMS "Programs That Make a Difference" Award, and 2008 AMS Award for an "Exemplary Program or Achievement in a Mathematics Department" (see *Notices of the AMS* Vol. 55, no. 5, p. 598).

www.ams.org/notices/200805/tx080500598p.pdf

**". . . mathematical talent can be developed when graduate study is viewed as an apprenticeship . . ."**

**— Abbe Herzig**

of whom knew little about how to navigate and succeed in a graduate program.

The main attrition point was the qualifying exams; too many students were not passing them. Following attendance at a conference at the American Institute of Mathematics (AIM) on finding and keeping underrepresented students in the mathematical sciences, Lin and other UCSD staff determined the need to build up the infrastructure. Their goal was to foster a sense of community and support. They created a Summer Qualifying Exam program which included prep sessions run by senior graduate students. These sessions created better opportunities for peer mentoring. The intervention worked; 10 of UCSD's women and African American students passed their exams as a result of participation in the session.

engineering, describes a similar situation at Smith College, a private, liberal arts college for women in Massachusetts. With an open curriculum, students do not commit to pursuing mathematics as a major until their third year of study. The situation results in lack of academic preparedness that would have been provided through enrollment in key foundational courses. Frustrated and unable to catch up, students often opt out. With an average enrollment of 1,500 students, less than 2 percent (N=20) are mathematics majors.

To increase student interest and recruitment to the major, Smith launched the NSF-funded Center for Women in Mathematics in order to foster a culture and sense of community and provide intensive training in mathematics at the advanced undergraduate level. The Center also provides post-baccalaureate study for women who want to pursue a doctoral degree in mathematics.

**Feeling like a mathematician involves integration into the department community and developing a sense of belonging to the community — it is not usually enhanced by practices that aim to 'weed out' students, by practices that encourage competitive feelings among students, or by limited relationships with faculty.**

While large public universities must create structures to support students who come with wide backgrounds and levels of academic preparation, smaller, private undergraduate institutions face other types of challenges. Students who attend small, liberal arts institutions often have a wide variety of interests and do not decide they want to pursue graduate work in mathematics until late in their undergraduate careers. Ruth Haas, chair and professor of mathematics and

Small departments are often able to provide students with greater contact, help, and encouragement. On the other hand, students from smaller institutions may not develop the experience and skills needed to learn material independently or learn ways to get assistance. Graduates of small colleges may not perform well on the Graduate Record Exam (GRE) subject test because they have not had a wide exposure to a number of advanced topics; the subject GRE may not be measuring other skills they have developed as undergraduates at a liberal arts institution.Students at non-doctoral institutions can enhance their background for graduate work by participation in special summer programs such as Research Experiences for Undergraduates (REUs).


**Breakout sessions gave conference attendees opportunities to review presentations, discuss issues, develop insights and formulate strategies.**

## Graduate Education as an Apprenticeship

Often embedded in the varied institutional cultures is the commonly held belief that mathematics is a subject that is pure and objective, and that people are born with the talent and determination to succeed in mathematics. The logical extension, therefore, is that if one does not succeed, then one must not possess the necessary talent. It is a "deficit model" that Abbe Herzig, assistant professor of mathematics education at the State University of New York (SUNY) at Albany and a member of the conference organizing committee, has explored in her research on women and students of color in the graduate mathematical sciences. Trained in statistics, Herzig noted in her conference presentation that there is much evidence that mathematical talent can be developed when graduate study is viewed as an apprenticeship, in which doing (not simply observing) the authentic work of the craft and interacting with the master crafts people is stressed.

Extending the apprenticeship model to mathematics may prove useful. In this paradigm becoming a mathematician involves the following:

(1) learning to do mathematics (to think like a mathematician),

(2) learning the norms, practices and other tacit knowledge of the discipline (acting like a mathematician), and

(3) developing an identity as a mathematician (feeling like a mathematician).

Historically, the focus of graduate education has been only on thinking like a mathematician. To learn to act like a mathematician one needs to participate with more experienced mathematicians in the practices of mathematics — learning how to do research, collaborate, write papers, give research talks, participate in conferences, teach, write grant proposals, obtain tenure, and balance career with other life issues. Feeling like a mathematician involves integration into the department community and developing a sense of belonging to the community — it is not usually enhanced by practices that aim to 'weed out' students, by practices that encourage competitive feelings among students, or by limited relationships with faculty.

## UNIVERSITY OF NEBRASKA

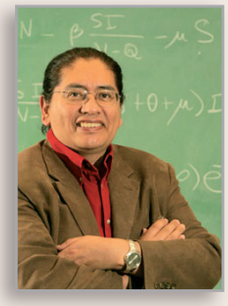
The University of Nebraska Mathematics Department involves graduate students in the full range of its activities — teaching, outreach, and scholarship. The department has also gained a well-deserved reputation for success with female graduate students. At the University of Nebraska 37 of 79 (47 percent) of the current teaching assistants are women and during the past ten years, 20 of the 55 PhDs awarded by the department went to women. Based on their outstanding success in mentoring female graduate students in the 1990s, the department received a Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring in 1998. The 2000 National Doctoral Program Survey conducted by the National Association of Graduate-Professional Students ranked Nebraska first out of all mathematics graduate programs included in the survey in nearly every category, including Overall Satisfaction.

The department has an extensive outreach program.* They offer a Math Day for high school students; an REU; a Mentoring through Critical Transition Points program; a summer program called All Girls All Math; an REU in Theoretical Ecology, and a bridge program for undergraduates to graduate work, called IMMERSE = Intensive Mathematics: a Mentoring, Education and Research Summer Experience.

Find more information on the University of Nebraska mathematics graduate program at www.math.unl.edu/graduate/prospective/

*www.math.unl.edu/programs/

## Carlos Castillo-Chavez



Conference Plenary Speaker Carlos Castillo-Chavez is a University Regents and a Joaquin Bustoz Jr. Professor at Arizona State University (ASU) and founding director of the Mathematical, Computational and Modeling Sciences Center and the Applied Mathematics in Life and Social Sciences program at ASU, which supports 20 undergraduate students from underrepresented minority groups.

Born in Mexico, Castillo-Chavez says that he never thought about becoming a mathematician or scientist. "In fact, I had a strong desire to become either an actor or a hotel manager!" He immigrated to Wisconsin in 1974 where he held a number of jobs before returning to school at the University of Wisconsin where he majored in Spanish literature and mathematics, earning a bachelor's degree in 1976. He completed a master's degree in pure mathematics in 1977 at the University of Wisconsin-Milwaukee, and earned a PhD in applied mathematics at the University of Wisconsin-Madison in 1984. He taught for a year at the University of Tulsa in Oklahoma before accepting a post-PhD position in the Department of Ecology and Evolutionary Biology at Cornell University, working under the mentorship of Simon Levin. He joined the faculty at Cornell University in 1988 as an assistant professor of biomathematics, was promoted to associate professor in 1991, and to full professor in 1997.

Castillo-Chavez's academic journey provides critical insight into his philosophy on increasing minority representation in mathematics. "I want others to be able to have the same opportunities as myself." In 1996, Castillo-Chavez co-founded

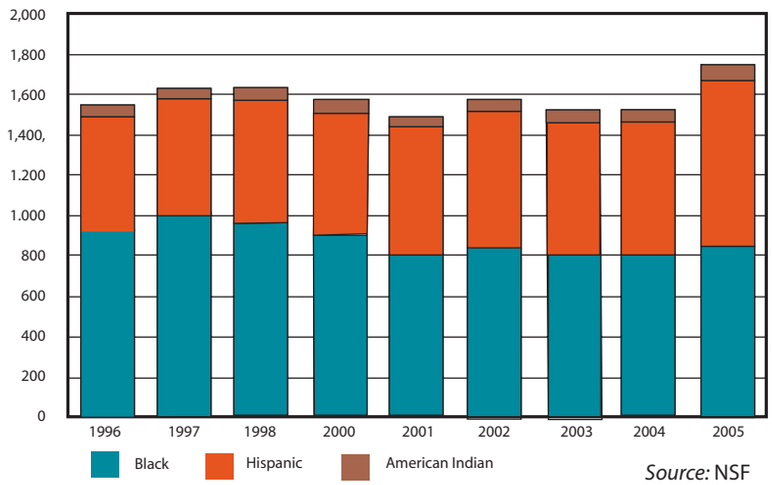
# Models of Creativity,

## Historically Black Colleges and Universities,

**ONE OF THE KEY OBJECTIVES** of the *Promoting Diversity* forum was to raise awareness and to explore programs that have been successful in recruiting, retaining, and graduating women and underrepresented minorities in mathematics, while also better understanding those factors that inhibit success. Toward this end, while it is clear that large universities are the largest producers of mathematics PhDs from all groups, other types of institutions — liberal arts and women's colleges, HBCUs, and other minority-serving institutions — are also a major conduit for students at the baccalaureate level who continue in graduate programs in STEM. In addition to college- and university-based programs (such as those mentioned above), professional societies, affinity groups, and nonprofit educational advocacy and support organizations have also developed models of creativity, innovation, and success.

**HBCUs.** Though disproportionately low, the number of bachelor's degrees awarded to underrepresented minorities in the mathematical sciences has been relatively stable (*Figure 3*). The largest producers of African Americans earning the baccalaureate degree in mathematics are HBCUs. The nation's 105 HBCUs constitute less than one percent of the U.S. higher education community, but account for 21 percent of undergraduate degrees awarded to African Americans in STEM. This is a precipitous

**Figure 3: Undergraduate Mathematical Science Degrees Awarded to Minorities, 1998-2005**




*Source:* NSF

# Innovation, and Success

## Hispanic-Serving Institutions and Women's Colleges

decline from the 36 percentage share in 1977, due in large part to the ability of African Americans to select from a variety of higher education options and intensive strategies by large universities to recruit high-achieving African American students. The top two baccalaureate-degree producers of African Americans in mathematics and statistics in 2007 were Morehouse College and Spelman College, two historically black, private, undergraduate liberal arts colleges located in Atlanta. Morehouse is a single-sex HBCU for men and Spelman is single-sex HBCU for women, each enrolling an average of 3,000 and 2,000 students respectively.*

Despite an overall decline in the number of African Americans attending HBCUs, these institutions continue to serve as major baccalaureate-origin institutions for African American doctoral degree recipients in STEM. In 2006, 33 percent of African American science and engineering doctoral recipients received their baccalaureate degrees from HBCUs, more than any other type of institution for the period covered. Clearly graduate mathematical sciences programs interested in attracting minorities who can succeed in doctoral programs should recruit and set up partnerships with HBCUs.

*www.diverseeducation.com/MathAfricanAmerican.asp


**Ellen Kirkman, Wake Forest University presents "Framing the Issues: What the Data Show, and What We Know about Diversity in the Mathematics Community."**

with Herbert Medina the Mathematical and Theoretical Biology Institute (MTBI) at Cornell. MTBI mentors, fosters, and supports research activities primarily among underrepresented minority undergraduate and graduate students from various universities who are working in the mathematical or statistical sciences. In its first five years (1996 to 2000), MTBI mentored and trained more than 106 minority undergraduate students in mathematics. About 47 percent of these students were enrolled in some of the most selective U.S. graduate programs in these fields in the nation and are either completing, have completed, or have entered the professional workforce. Erika Camacho was the first MTBI participant to earn her doctoral degree, which she did in mathematical biology in 2003. Miriam Nuno graduated in 2005 with a PhD in mathematical and computational biology. She did postdocs at Harvard and UCLA and is now a biostatistician at Cedars Sinai in California. Johnny Guzman also graduated in 2005 but with a PhD in numerical analysis. After a postdoc at the NSF, Guzman is now assistant professor of applied mathematics at Brown University. More recently, Karen Rios-Soto graduated from Cornell University in 2008 with the PhD in mathematical and momputational biology. She is assistant professor of mathematics at the University of Puerto Rico, Mayaguez.

Castillo-Chavez has received numerous honors for his work, including a Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring in 1997 and the American Association for the Advancement of Science Mentor Award in 2008. Reflecting on his impact on the field, Castillo-Chavez says that, "I love impacting young people, encouraging them to get their PhDs while working on questions that matter to them and their communities." He goes on to point out that the students "are the engines of improvement in our society. There's nothing like having the job that I have."

## Karen Uhlenbeck

*A mathematician acclaimed for her outreach programs that develop the mathematical talents of promising young women.*

Karen Uhlenbeck* is the Sid W. Richardson Foundation Regents Chair in Mathematics at the University of Texas in Austin. She is a member of the National Academy of Sciences and the American Academy of Arts and Sciences. She has received many prizes and awards, including a MacArthur Prize Fellowship in 1983 and an AMS Steel Prize for Seminal Contribution to Research in 2007. Many women view her as the role model of a successful mathematician.

Uhlenbeck has been involved in outreach programs. Her particular focus is developing the mathematical talent of promising young women. She was one of the founders of the IAS/PCMI Park City Mathematics Institute** which has programs for high school teachers, undergraduates, graduate students, post docs, and senior researchers (both men and women). In 1994, she and other successful women mathematicians became concerned that despite the fact that nearly half of undergraduate mathematics majors have been women for quite some time, there was not a large cohort of successful younger women mathematicians following them; hence with Chuu-Lian Terng she organized the program for women and mathematics that is held each year at the Institute of Advanced Study.* The program is an 11-day intensive workshop that brings

* http://rene.ma.utexas.edu/users/uhlen/

** http://pcmi.ias.edu

# The Way Forward:

There are more than 4,000 colleges and universities that provide higher educational access for the country's diverse student population. And while each institution presents its own particular culture, many of the initiatives highlighted at the *Promoting Diversity* forum provide models that may be adapted in a variety of institutional environments and contexts, either in whole or in part. Some models merged from the panel on "What Can Be Done to Broaden Participation in the Mathematical Sciences?" moderated by David Mandersheid, dean of the College of Arts and Sciences at the University of Nebraska, while others surfaced at various points over the three days of the conference. We summarize those interventions here.

## Recruiting and Admission

Several mathematics graduate programs that have been successfully increasing their diversity began by creating formal networks with undergraduate institutions with large numbers of women or minorities. In such networks, faculty from the research university visit the undergraduate institution, delivering lectures and hosting some summer activities for the undergraduates. Several universities have developed successful programs for high school students — just as professional sports start building athletes as youth, universities can begin developing the talent of students before they enter college.

Successful mathematicians mentioned programs they attended as high school students or undergraduates as powerful influences in their decision to become mathematicians. Recruiting weekends are helpful ways of attracting students. At recruiting activities, the graduate student attendees noted how important it is that minorities are present as faculty and students or alumni; it is helpful to explicitly make clear to recruits that diversity is valued in the department. Graduate programs need to rethink their reliance on the Graduate Record Exam and other traditional measures in making admission decisions — there may be better ways to distinguish between prior performance and promise. Faculty from the University of California at Berkeley explained that the institution now admits promising students who are not quite ready for their graduate program to a two-year program that is a "pre-PhD Program."

# Building Diverse Communities

## Supporting Graduate Students as Learners and as People

Panelists and the audience shared experiences and activities, and a number of creative ideas emerged on ways to improve graduate programs in mathematics. We highlight several of those here:

- ✓... communicate an expectation of success, rather than one of failure;
- ✓... admit fewer students so that less "weeding out" occurs;
- ✓... provide both peer and faculty mentoring to all students;
- ✓... organize problem sessions for first-year graduate courses (problem sessions are led by faculty or advanced grad students);
- ✓... select first-year course instructors carefully;
- ✓... hire advanced graduate students to help students prepare for preliminary exams;
- ✓... modify program requirements to correspond to educational objectives;
- ✓... invite speakers (particularly women and people of color) to give talks that are accessible to all graduate students and to interact with current students;
- ✓... send students to conferences and help them prepare to present research results;
- ✓... allow students more time to master the basics before beginning advanced courses;
- ✓... provide graduate students with early research experiences and with opportunities to get involved in the work of the department and mathematics community more broadly;
- ✓... sponsor social events for students and faculty ;
- ✓... create a faculty-student advisory board;
- ✓... build an infrastructure for mentoring, help faculty explore the meaning of mentoring, and develop a principled way to match students with mentors;
- ✓... create an advising committee for first-year graduate students that monitors student progress after each exam in each course;
- ✓... provide training for teaching and involve students in teaching advanced undergraduate course;
- ✓... provide internships for students to learn about working in industry.

**Several universities have developed successful programs for high school students — just as professional sports start building athletes as youths, universities can begin developing the talent of students before they enter college.**

together research mathematicians with undergraduate sophomores through seniors and advanced graduate students. The program includes lectures and research seminars on a (changing) focused mathematical topic, mentoring, discussions on peer relations, an introduction to career opportunities, and a women in sciences seminar. The participants experience the exciting intellectual atmosphere of IAS — they share war stories and articulate hopes and fears. Uhlenbeck told the forum audience, "undergraduates are to a great extent very naïve — and nobody makes it through graduate school naïve." Her program has been successful in helping highly talented women develop successful mathematical careers.

* www.math.ias.edu/wam

**"For example, if an SAT test begins with a question asking the student's gender, women do worse and men do better than if the question on gender occurs at the end of the test."**

**Joshua Aronson, The Steinhardt School, New York University.**

As associate professor of psychology in the Steinhardt School of Culture, Education and Human Development at New York University, Aronson (at right) has been studying the psychology of stigma for more than a decade, focusing on ways to remediate race and gender gaps in educational achievement and standardized test performance that derive, in his estimation, from stereotypes and stigma. Aronson and his research team have made some interesting observations that build on and sometimes divert from previous theories of race and gender gaps that focused on poverty, culture, or genetics. "We have found that we can do a lot to boost both achievement and the enjoyment of school by understanding and attending to these psychological processes, thereby unseating the power of stereotypes and prejudice to foil the academic aspirations of the young people who, just by virtue of being born black, brown, or female, are subjected to suspicions of inferiority."

## Unseating the Effect of Stereotypes

Programs where women and underrepresented minorities succeed are ones that work deliberately and intentionally to make everyone feel included and welcome and where these goals are shared by the whole department. Unfortunately, negative effects on women and underrepresented minorities are often subtle. These tacit interactions, bound up in experiences that influence how we respond, react and behave, are what Joshua Aronson describes as "stereotype threat," a term he and his mentor coined to described popularized but ill-conceived notions such as 'girls can't do math.' Aronson presented results of his research that demonstrate that when subjects are reminded of the stereotypes, their performance is affected. For example, if an SAT test begins with a question asking the student's gender, women do worse and men do better than if the question on gender occurs at the end of the test. "Stereotype threat," explains Aronson, "engenders a number of interesting psychological and physiological responses, many of which interfere with intellectual performance and academic motivation."

## Mentoring Clusters and "Tiered Mentoring"

Women and underrepresented minorities who succeed often point to mentors who have helped them along the way. Mentoring is more than academic advising but involves building sustained relationships and an appropriate infrastructure to support the mentoring process. These mentors may be found among senior graduate students, undergraduate faculty, summer programs such as EDGE, MTBI/SUMS (see sidebars on pages 4 and 6) and REUs. Mentoring is a cornerstone of the EDGE program co-directed by Bozeman and Hughes. EDGE uses several forms of mentoring:

- ✓...Advanced graduate student mentors during the summer session,
- ✓...Mentoring by the directors and some of the EDGE faculty,
- ✓...An identified graduate faculty mentor in the student's department during the first year,
- ✓...Mentoring by peers through an electronic forum/bulletin board.

As the EDGE program has grown, the infrastructure to support mentoring has had to be expanded as well. Bozeman and Hughes piloted a new structure, using an NSF ADVANCE grant. The two mathematicians created several regional mentoring clusters in geographic areas where mathematics graduate students from several institutions could gather with a few junior faculty and have one or two senior women mathematicians as cluster leaders. They termed the model "tiered-mentoring," with senior women mentoring junior faculty and both mentoring graduate students. One EDGE program participant, who has since earned the doctoral degree, wrote of how the mentoring program "saved her."


**Duane Cooper, associate professor of mathematics at Morehouse College, moderated a panel that explored these varied "institutional cultures"—from the small liberal arts and women's colleges, to the broad spectrum of minority-serving institutions to major research universities.**

*The mentoring clusters were a chance to step outside the small world of my department and thesis, reflect out loud about my experiences, and hear those of others. They provided vital perspective on what I was doing and why. …Talking with the women in classes below, I was energized to hear their early enthusiasm and offer my advice for the trickier parts of the process. Talking with the women in classes above and other mentors, I was reminded of where I hoped to be in a few years (in an academic setting, the whole reason for my pursuit of this degree) and I received invaluable advice and perspective about the process ahead.*

Programs such as EDGE (see sidebar page 6) and Project NExT (New Experiences in Teaching —a network of new faculty) have found networks useful in linking people who feel isolated and providing them with a supportive community. Professional organizations with a big stake in the next generation of mathematical sciences faculty are interested in being more involved with graduate students, and could be used in establishing new networks. T. Christine Stevens, professor of mathematics at Saint Louis University and director of Project NExT, discussed the mentoring that new faculty receive through this MAA-sponsored network. She presented NExT as a model that professional societies might adapt for mentoring graduate students as well. A professional society in mathematics with a commitment to mentoring though its structured program is the Association for Women in Mathematics (AWM). The interest of AWM in promoting diversity was also reflected by the large number of AWM presidents (current and past) in attendance at the conference.

## What Students Can Do

When picking a graduate program, students can consult the publication *Assistantships and Graduate Fellowships Guide to Graduate Programs** to find information such as level of financial support, duties, fees, how many students are finishing degrees, and in what fields. If possible, students can visit the institution. They can look for welcoming programs in which they are expected to succeed. They can find, build, and sustain intellectual and other communities that will provide support through the graduate years, and learn the explicit and implicit expectation for success in their program. When they find they have deficiencies in their background, they can seek advice and work to eliminate them.

They should

- not be afraid to tell advisors that they need to take bridge courses to better prepare for graduate work;
- form study groups, mentor and support other students,
- find and sustain relationships with mentors;
- not compare themselves to others and fuel a graduate culture that is competitive,
- help departments attract other women and under-represented minorities,
- speak up about racism, sexism, and inappropriate behavior, and,
- speak up about how graduate students can work as agents of change to make programs better for others that follow.

* www.ams.org/employment/asst.pdf

**The Students' Perspective panel. The conference was unique in its exchanges between faculty and graduate students from different types of institutions.**

# The Case for Diversity

Donna Nelson, associate professor in the Department of Chemistry and Biochemistry at the University of Oklahoma, has noted that, "Underrepresented minorities are projected to constitute almost 32 percent of the American population by 2020. Therefore, proactive steps should be taken now in order to insure the proportionate inclusion of such a large part of the U.S. population in science and engineering throughout all levels of academia." ("A National Analysis of Minorities in Science and Engineering Faculties at Research Universities" by Dr. Donna J. Nelson, supervising Christopher N. Brammer and Heather Rhoads, October 31, 2007.*)

When we focus attention on faculty in the mathematical sciences, the data is equally distressing. Take, for example, a current snapshot of the race/ethnicity of mathematical sciences faculty provided in the CBMS 2005 report: TABLE F-5; *Figure 4,* showing that there are few underrepresented minorities at all levels and kinds of institutions. Data provided by Dr. Nelson show that the percentages of minority faculty at research universities may be even declining in mathematics: TABLE 1; for example, the percentage of underrepresented minority assistant professors in mathematics at her group of top 50 research universities was 6.0 percent in 2002 and 2.3 percent in 2007.

The percentage of underrepresented minority students among doctoral mathematical sciences graduate students who are U.S. citizens was 9 percent in 2007: THIRD REPORT 2007 TABLE 6B. These data are encouraging and provide a basis for increasing productivity in the near future, since, according to AMS reports, only 4.8 percent of the new PhDs were from the underrepresented groups in 2006-2007. NSF data show a slight increase in the number of all underrepresented minority graduate students in the mathematical sciences (FIGURE 5). Diverse magazine provides yearly ranked lists of the institutions that are awarding doctoral degrees to minorities in mathematics and statistics.**

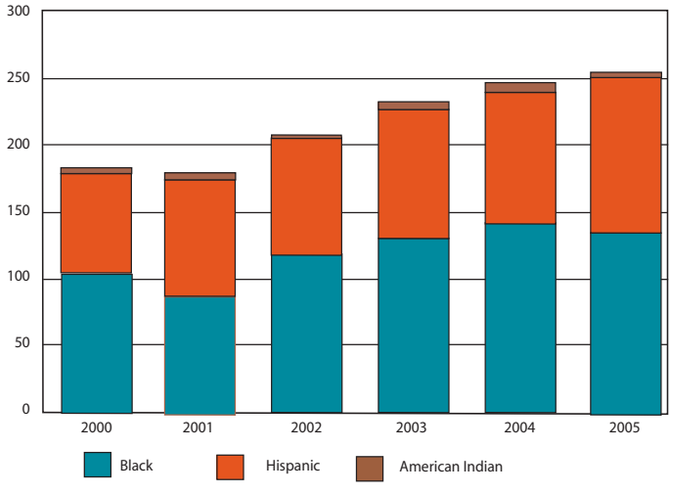
* http://chem.ou.edu/~djn/diversity/briefings/15Jan04Briefings.html (pdf)
** www.diverseeducation.com/

***Figure 4:*** **Gender and Ethnicity of Mathematical Science Faculty Fall 2005**

| Full-time Faculty | Asian | Black | Hispanic | White | Other |
|---|---|---|---|---|---|
| **Math PhD level** | | | | | |
| % Female | 3 | 0 | 1 | 14 | 0 |
| % Male | 12 | 1 | 2 | 66 | 1 |
| **Math MA level** | | | | | |
| % Female | 4 | 1 | 2 | 22 | 1 |
| % Male | 10 | 3 | 2 | 54 | 2 |
| **Math BA level** | | | | | |
| % Female | 3 | 1 | 1 | 25 | 2 |
| % Male | 6 | 2 | 2 | 57 | 3 |
| **Stat PhD level** | | | | | |
| % Female | 7 | 1 | 0 | 16 | 1 |
| % Male | 18 | 1 | 1 | 55 | 2 |

*Source*: CBMS 2006 Survey Report: Table F-5

***Figure 5:*** **Minority First Year Graduate Mathematical Science Enrollment 2000-2005**




*Source*: NSF, *Women, Minorities & Persons with Disabilities*, 2007 (NSF 07-315)

# Conclusion

The challenge of planning a forum to address the issues in graduate degree completion faced by women and those from underrepresented groups was considerable. Nevertheless, this forum demonstrated widespread agreement for the need to enhance diversity of U.S. graduate programs in mathematics, as well as a serious commitment from the mathematics community to institute change. While there are modest signs of hope emerging from the most recent NSF data that show a slight increase in the number of all underrepresented minority graduate students in the mathematics sciences, this increase must be accompanied by more targeted and sustained support of these students. The *Promoting Diversity* forum and these proceedings beckon us to engage in bold and creative change.

**From left: Sylvia T. Bozeman, Spelman College; Kathleen O'Hara, associate director of the Mathematical Sciences Research Institute; Linda Pace, EDGE program coordinator; Ellen Kirkman, Wake Forest University; and Abbe Herzig, SUNY-Albany.**

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## Notes

According to the U.S. Census Bureau, minorities, now roughly one-third of the U.S. population, are expected to become the majority in 2042, with the nation projected to be 54 percent minority in 2050. By 2023, minorities will comprise more than half of all children. [www.census.gov/Press-Release/www/releases/archives/population/012496.html] Accessed: 02Jan2008. The U.S. Census Bureau defines ethnic and racial minority groups as African Americans, Hispanic, Native American (which includes Alaskan Natives and American Indians), Asian American, and Pacific Islanders.

In this document, the term "underrepresented" refers to racial and ethnic minority groups which the NSF identifies as pursuing and earning degrees in science disciplines disproportionate to their numbers in the U.S. population. The groups include: African Americans, Hispanics/Latinos, Native Americans and Alaskan Natives.

# INDEX

## People*



** An email address indicates that this person is a member of the Forum Organizing Committee.*

## Organizations



## Topics



## Colleges and Universities

# Promoting Diversity at the Graduate Level in Mathematics

## Proceedings of a National Forum

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