

## Chapter 20

# An EDGE in Mathematics for Women: The Enhancing Diversity in Graduate Education Program

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**Abstract** The EDGE Program (Enhancing Diversity in Graduate Education) was initiated in 1998 by two mathematics professors from women's colleges, with the goal of helping women persist in graduate programs in the mathematical sciences. The program initially focused on the transition to and preparation for the first year of graduate school, with a commitment to diversity among participants, faculty, and staff. A four-week summer session featured courses that bridge undergraduate and graduate work, study groups, graduate student mentors, and professional and academic visitors, as well as social and team-building activities. Gradually EDGE expanded to support women throughout their graduate school and professional careers. What began with two founders and eight EDGE participants has grown to a diverse community of alumnae, more than 48% of whom are from groups underrepresented in the mathematical sciences. This article chronicles the impact of the EDGE Program on participants and the emergence of a new generation of leaders in the mathematics community. Lessons learned that may benefit others involved in related efforts are shared.

**Keywords** EDGE program • Mentoring women • Underrepresented mathematicians • Women mathematicians • Graduate students

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## 20.1 The Founding of the EDGE Program

No one is born smart. No one is born knowing how to read, right? No one is born knowing how to do math, or no one is born knowing how to play the flute—all of that comes with a lot of hard work... The only way you know how to read is that you keep trying.”—First Lady Michelle Obama at Savoy Elementary School on May 24th, 2013.

Chaos theory offers a conceptual framework for understanding how the EDGE Program increased the participation of women, including those from underrepresented groups, in the American mathematics community. A principal feature of chaos theory is the so-called “butterfly effect,” whereby a small, seemingly remote disturbance can have a significant impact on events. In the case of the EDGE program, the “butterfly” was mild-mannered American civil rights activist and mathematician Lee Lorch. At the Joint Mathematics Meetings in Atlanta in 1990, he introduced Rhonda Hughes of Bryn Mawr College and Sylvia Bozeman of Spelman College with the simple utterance, “You two should know one another. You care about the same issues.” The two women’s college mathematics department chairs took his words seriously; that quiet introduction spurred a series of events that resulted in a powerful metaphorical and literal disturbance within the mathematical community known as the EDGE Program.

Initially, Hughes and Bozeman established the Bryn Mawr-Spelman Summer Mathematics Program<sup>1</sup> in order to provide research experiences in mathematics for first- and second-year women college students. The program, which ran for four summers, sent a noteworthy 60 percent of its participants to graduate programs in the mathematical sciences. However, after receiving feedback from their own alumnae and noting the number of well-prepared women who left graduate programs in mathematics for both academic and non-academic reasons, Hughes and Bozeman determined that there was an even greater need to support women graduate students. These concerns about graduate student attrition had already garnered some national attention. In 1992, the National Research Council conducted a study, “Educating Mathematical Scientists: Doctoral Study and the Postdoctoral Experience in the United States.” One goal of the study was to determine what factors make certain doctoral programs in the mathematical sciences successful in producing large numbers of domestic Ph.Ds., including women and underrepresented minorities. The committee conducting the study observed in its site visits that departments that promote the success of women and underrepresented minorities often find that those students do indeed succeed. Nevertheless, there was still no perceptible national effort to address both academic and non-academic issues leading to high attrition rates, especially among seemingly well-prepared women in mathematics.

Driven by a steadfast commitment to a more diverse mathematics community, Hughes and Bozeman co-founded the EDGE Program to provide broad transitional support for women, particularly women from underrepresented groups, entering

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<sup>1</sup>This program was also called the Spelman-Bryn Mawr Summer Mathematics Program for two years.

mathematics doctoral programs. They received the support of students, faculty, and administrators at their home institutions, as well as from the National Science Foundation (NSF). Lloyd Douglas, an NSF Program Officer who strongly believed in the viability of the EDGE idea, searched relentlessly to secure partial funding for the initial year. In addition to the NSF, the program was supported by the Andrew W. Mellon Foundation, the National Security Agency, and the many institutions that hosted the program. For the first four years, EDGE alternated between Bryn Mawr and Spelman Colleges. Subsequently, ten colleges and universities across the US (listed later) hosted the program.

The following quote, widely attributed to anthropologist Margaret Mead, aptly describes the national community that banded together to support the EDGE program: “Never doubt that a small group of thoughtful, committed citizens can change the world; indeed it is the only thing that ever has.” In this case, the world that has been changed is that of American mathematics. At the start of the 21st century, the American Mathematical Society (AMS) designated EDGE as a “Mathematics Program That Makes a Difference,” noting its “success in improving the diversity of the profession of mathematics in the United States” [8]. The EDGE Program has had a positive, significant impact on the number and diversity of American women earning mathematics doctoral degrees and serving as leaders in the scientific community, as demonstrated in the following sections. Nonetheless, as the EDGE Program joins other entities addressing an entrenched problem in the United States, the need for continued intervention remains strong.

## **20.2 The EDGE Program Philosophy and Goals**

The EDGE philosophy is that students who delight in the study of mathematics, perform exceptionally well at the undergraduate level, and have been identified as possessing abundant potential by their undergraduate mathematics professors are capable of success at the graduate level. This philosophy is a response to a frequent and unfortunate phenomenon witnessed by Bryn Mawr and Spelman faculty, as well as faculty at colleges and universities around the country: well-prepared, academically talented, undergraduate women are accepted into mathematics graduate programs, only to leave those programs without the intended degree. The resultant mathematics graduate program attrition represents a substantial loss of talent in and negatively impacts the gender and racial diversity of the mathematics community. Graduate school is often a high-performing student’s first encounter with perceived failure. A young woman who performs below her own high expectations may conclude that she does not have what it takes to succeed. On the other hand, if she is provided with an understanding of the culture of graduate school, a standard of measurement by which to judge her performance, a guide for realistic expectation, and a community within the department to trust for advice, evidence suggests that she can and often does succeed. Further, women who come from small undergraduate mathematics departments with few advanced mathematics elective

options often believe that they were not exposed to enough mathematics necessary to succeed.

The EDGE philosophy affirms that a student who excelled in her undergraduate mathematics department is capable of earning a doctoral degree in the mathematical sciences. In support of this philosophy, the EDGE program established two primary goals:

- Provide academic enrichment, cultural exposure, and mentoring to bridge the transition from undergraduate to graduate mathematics programs for women from diverse backgrounds.
- Diversify the mathematics community in the United States.

As EDGE evolved, the directors established the following secondary goals in response to needs of program participants:

- Mentor women during and after graduate school in order to provide timely support, and to produce leaders in the scientific community.
- Establish a community of participants, alumnae, faculty, and staff that provides support, tiered mentoring, and networking opportunities.

Driven by the passion and extraordinary potential of EDGE participants, faculty, staff, directors, and supporters, EDGE has evolved into a dynamic national organization. While holding true to its original mission of supporting diversity in mathematics graduate education, EDGE has cultivated a built-in agility that responds to emergent participant needs.

### **20.3 Components of the EDGE Program**

One of the greatest challenges for new mathematics graduate students is navigating the transition from undergraduate to graduate mathematics departments. During this academic and cultural transition, students must forge relationships in a new culture, learn unwritten rules, and maintain their own identities and values. As such, the central component of the EDGE program is a four-week summer session designed to:

- Provide bridge courses in algebra and analysis that connect undergraduate and graduate mathematics.
- Provide engaging activities that introduce entering students to the culture, rigor, pace, study expectations, and challenges of graduate mathematics as well as to mathematicians with whom they can relate.

The summer session bridge courses/workshops and activities are led by a diverse staff of primarily women mathematicians and advanced graduate students. They assist participants in learning to work, speak, and socialize across academic, cultural, social, and other boundaries. For example, the “Difficult Dialogues” seminar is designed to foster an appreciation for individual talents and uniqueness.

Through guided activities, participants build self-confidence in negotiating new environments with people from diverse backgrounds. The summer session also provides participants with opportunities to hear graduate students and faculty discuss their experiences and offer advice on navigating academic, social, and political encounters in mathematics doctoral programs. The preview of graduate school that the EDGE summer session provides offers an “edge” that prepares students for the year ahead and supports their abilities.

The EDGE Program has evolved to include additional components that provide continuous contact, support, and mentoring to participants beyond the summer session. The EDGE Reunion Conference is a weekend during which the previous year’s participants, having completed their first year of graduate school, return to the EDGE summer session. These students reconnect with EDGE directors, faculty, and graduate student mentors for debriefing and advice. They meet and speak with recent EDGE Ph.D. recipients, share stories of challenges they had to overcome with current EDGE participants, and attend research talks. Students also share their experiences in their own words with a special sensitivity to the audience. For example, one EDGE alumna explained to current EDGE students that learning to handle graduate mathematics courses was “a lot like learning to walk in high heels on a rocky path.” The Reunion Conference provides current and past participants with palpable evidence of EDGE’s warmth, support, and singleness-of-purpose.

The EDGE program also supports additional activities designed to strengthen community, encourage professional growth, celebrate diversity, and showcase the work of current and past participants at national and international venues. Activities have included:

- *An annual EDGE reunion held at the annual Joint Mathematics Meetings (JMM).* Although this annual gathering is less intensive than the summer session reunion, it continues to establish mid-academic-year contact and fosters networking among EDGE community members at all academic and professional stages.
- *Several EDGE-specific JMM Special Sessions.* The sessions titled, “Pure and Applied Talks by Women Mathematics Warriors,” have been regularly organized by past EDGE participants and graduate student mentors at the 2014, 2015, 2016, and 2017 JMM.
- *An EDGE-specific AWM Research Symposium Special Session (in 2015 and 2017).* The organization and leadership for the sessions have been provided by EDGE participants and mentors.
- *An EDGE-specific mini-symposium at the 7th International Congress on Industrial and Applied Mathematics (July 2011, Vancouver).* The mini-symposium, titled “Applications from the EDGE,” was co-organized by an EDGE faculty member and a past participant. The four symposium speakers were all past EDGE participants, including three from underrepresented groups.
- *Small research funding opportunities for current and past participants.* Since the beginning of the EDGE Program, students have been allocated a small research fund to be used during their first graduate school year following the initial four-week summer session. In later years funding was made available to support

research travel by advanced graduate students and recent PhDs. Many first-year students apply the funds to books while advanced graduate students typically use the funds to offset costs of traveling to attend or present at scientific conferences.

- *EDGE newsletters*. Two newsletters, which were produced and distributed by past EDGE participants in 2010 and 2012, provided a venue for reporting on personal and professional accomplishments and for maintaining connectivity. Later the community turned to other media platforms to achieve some of these goals.
- *EDGE-specific social media platforms and a listserv*. These mechanisms support communication among EDGE community members. The directors hope to identify a method for evaluating the impact of these technologies.
- *Research Mini-Sabbaticals*. Funding is provided, by request, to past participants who are advanced graduate students, recent PhDs or junior faculty to advance the work and intellectual growth of recipients as well as increase their visibility within the mathematics community. A Research Mini-Sabbatical may provide funding to spend two to six weeks working with a collaborator.

As the number of EDGE participants grew, it became a significant challenge to support and mentor every past participant until she earned the doctoral degree. Attempts to address this challenge led to the formation of regional Mentoring Clusters. Although peer mentoring seemed to occur organically, a formal structure was needed to increase personal contact with senior faculty. In order to meet this challenge the co-directors established Mentoring Clusters in geographical regions where there was a significant number of EDGE students in graduate programs. Each cluster consisted of a group of graduate students and one or two designated senior faculty, as well as junior faculty and post-docs, and included graduate students not connected to EDGE. Mentoring Clusters usually consisted of a dozen or so participants from several institutions. The primary goal of each cluster was to bring women mathematicians (often including statisticians) together a few times each year to discuss the concerns of students and receive advice on teaching, research, and personal or community issues. In some clusters students presented their research to receive input from the group. Some clusters planned events such as a one-day symposium or an outreach project or joined other local groups in doing the same. Clusters were established in six geographical regions: Southern California, Georgia, Indiana, North Carolina, Iowa, and the mid-Atlantic region. A seventh cluster was based on a common passion for mathematics education. Clusters were successful due to the extraordinary commitment of the senior women mathematicians and statisticians, several of whom were past faculty, speakers or local coordinators of the EDGE Program.

Through these efforts to provide more direct mentoring, several regional research symposia and other outreach activities have been organized, inspired, and often co-sponsored by Mentoring Clusters. Early on, a one-day Women in Math Symposium (WIMS), which emerged as a co-sponsored standard activity of the Southern California Mentoring Cluster, included a keynote address, opportunities for women graduate students and faculty to offer short research talks, and dedicated time

to collaborate on a research problem. In 2017 the 10th Annual Symposium for Women in Mathematics in Southern California was held with other funding and in cooperation with AWM. The first mid-west WIMS, held at the University of Illinois-Chicago in 2013 gives credit to the “successful WIMS held in Southern California” for its organization. The one-day North Carolina Symposium for Women in Mathematics and Statistics, was co-sponsored by the North Carolina Mentoring Cluster in 2011. Other clusters, including those in Indiana and Georgia, joined local efforts to host lectures by women mathematicians. The Iowa Cluster organized a one-day conference for undergraduate women in mathematics and statistics to encourage preparation for graduate school. These one-day regional symposia and other gatherings are intended to strengthen networks, encourage collaborations, and foster mentoring relationships within a particular geographic region.

Feedback from the EDGE mentoring clusters indicated a need for continued direct interaction between women mathematicians at all stages of their careers. Reports from the clusters, describing the responses of students, suggested that they were very effective in providing critical support to graduate students. Among the most active is the North Carolina cluster in which every woman in the original cohort earned the doctoral degree; it currently continues with a new cohort of graduate students and three committed senior women from three institutions. The Iowa Cluster, which began in 2010, inspired other local mentoring efforts and currently continues with local support.

## 20.4 EDGE Participant Statistics: 1998–2016

At the time of this writing, 71 EDGE participants have earned doctoral degrees, an indication that the primary goal of the program is being achieved. Intertwined with that goal is a focus on diversity. From its very beginning in 1998, the EDGE Program has been characterized by its commitment to diversity among participants, mentors, faculty, and staff. Of the 243 EDGE participants from 1998–2016, 117 women, or just over 48%, were from groups underrepresented in science and mathematics. According to NSF criteria, underrepresented groups include Alaska Natives, Native Americans, African Americans, Hispanics, Native Hawaiians, and other Pacific Islanders. Among EDGE faculty and graduate student mentors, 52% of faculty and 45% of mentors were from underrepresented groups. The eight participants in the first summer session, as well as the 13–15 participants in subsequent summer sessions,<sup>2</sup> added additional diversity to the program, including economic, geographic, and first-generation-college status.

Time-to-degree attainment varies for different individuals and is sometimes prolonged for women who seek to balance work and family life during graduate

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<sup>2</sup>The phrase “subsequent summer sessions” refers to subsequent years other than 2007, a year when there was no summer session and no new participants.

school. In acknowledgement of this nonlinear trajectory, the academic attainment of EDGE participants from 1998–2009 is presented here in order to gain perspective on the long-term progress of the EDGE Program. Of the 134 women who entered the EDGE program during 1998–2009, 49% were White, 42% African American, 6% Latina/Chicana, 2% Asian, and 1% other. As of June 2016, 67 of the participants in this group had earned doctoral degrees, almost all in the mathematical sciences. At least 85% of EDGE participants earn at least one graduate degree. As would be expected, most participants entering graduate programs from 2010 to 2016 have not yet earned doctoral degrees and so no analysis is included for this group.

The necessity for a program that supports all women and yet targets the inclusion of women from underrepresented groups can be seen in the following data, based on AMS Annual Surveys [6]. According to that source, over the five academic years from 2005–2006 to 2009–2010, African American women earned only 3.7% of the doctoral degrees in the mathematical sciences earned by US women. Among those African American women, a noteworthy 27% of them were participants in the EDGE Program [4]. Within the EDGE cohorts, success in earning a doctoral degree varied along racial lines. That is, in the total of cohorts prior to 2010, where 50% have earned the doctoral degree, 59% of Caucasian participants and 41% of participants from underrepresented groups have achieved this initial goal. Some others are still matriculating.

Of course, statistics concerning degree attainment among EDGE participants tell only one part of the EDGE story. In the sections that follow, participants and the leadership reflect on the benefits of the program and its impact on the larger mathematics community.

## **20.5 EDGE Participants' Viewpoints: Coming of Age Mathematically in a Supportive Environment**

A distinguishing feature of the EDGE Program is that, after the four-week summer session, participants remain engaged with the program. They become members of a community that mentors them throughout graduate school and beyond. The EDGE PhD survey [3] provided an opportunity for past participants with earned doctoral degrees to discuss the impact of the EDGE program, including the summer session and the continuing community, on their success and development. This survey does not capture the voices of past participants who left or remain in the PhD pool, including many with earned Master's degrees. Nonetheless, EDGE PhD recipients have important insights to share about the impact of the program on their success.

The racial composition of the 36 EDGE PhD survey respondents—21 (58%) white and 15 (42%) from underrepresented groups—approximated that of the then-total EDGE participant group. Of the survey respondents, 73% were college faculty, 17% were in post-doctoral positions, and 10% were employed outside of academia.



Survey respondents reported that both the academic enrichment and the support and mentoring network that the EDGE community provided contributed to their academic success. They identified the following program components as either “somewhat beneficial” or “very beneficial” to their academic success: (For each item below, the percent of respondents that chose “very beneficial” is given. A third option of “not beneficial” was not chosen by any respondent for any item below.)

- The algebra and analysis courses of the EDGE summer session. (61%—very beneficial)
- Problem sessions conducted by advanced graduate student mentors. (84%—very beneficial)
- Planned social activities, including special weekly dinners. (71%—very beneficial)
- Diversity of the students and staff. (81%—very beneficial)
- Annual Reunion Weekend/Conference. (87%—very beneficial)
- Informal, unplanned activities with other EDGE participants. (79%—very beneficial)

Together these program components provided early exposure to the rigor and pace of graduate school and increased the students’ knowledge and confidence in key first-year courses, thereby easing the transition to graduate school. Looking beyond the first year, the foundation was established through EDGE for networking throughout graduate school and into the early careers of participants.

Participants in each summer session had different experiences since each year brought a different faculty, staff, and set of graduate student mentors, and a bonding of peers that was unique to that group. Nevertheless, most respondents rated their engagement with advanced graduate student mentors (81%-very beneficial) as one of the most valuable components of the EDGE Program. The graduate mentor problem sessions and their on-site housing provided time to collaborate on faculty-provided problems, as well as to engage in informal discussions about graduate life.

Some of the most compelling survey responses spoke to the value of the EDGE environment and culture, which respondents described as:

- Nonjudgmental.
- A setting in which students share in a common difficult experience.
- A climate in which students are comfortable revealing vulnerabilities.
- A space in which one’s ability to succeed in mathematics is not questioned.
- An environment that is absent of a recurring need to prove oneself.
- A “safe haven” during academic difficulties or periods of self-doubt or disillusionment.

With regard to mentoring, more than half of respondents reported being mentored by another graduate student from EDGE or from their graduate programs, receiving both practical advice and general encouragement. More than two-thirds reported mentoring other graduate students, often out of a desire for others to have a better experience than the mentor. In sum, respondents indicated that they benefited from

**Table 20.1** Population Percentages of US Women vs. Percentages of US Women Mathematics Doctoral Recipients [1, 9]

	Percentage of total US population in 2014	Percentage of US citizen mathematics doctoral recipients in 2014	Percentage of all mathematics doctoral degrees awarded in US in 2014
All Women	50.8%	28%	13.3%
Black/African American Women	6.5%	1.1%	0.5%
Hispanic/Latina Women	8.6%	0.5%	0.3%
American Indian/Alaska Native/ Pacific Islander Women	0.5%	0.4%	0.2%
Asian Women	2.8%	2.5%	1.2%
White Women	31%	21.5%	10.3%
Multiracial (not Hispanic) and Other	1.0%	1.7%	0.8%

exposure to women who were at different stages of their mathematical trajectories through both formal and informal contacts.

Thus far, we have summarized responses from the total group of EDGE survey respondents. However, the data suggest that persistence and degree achievement rates among United States graduate students in mathematics doctoral programs vary by both gender and race, with underrepresented women faring far worse than other women. According to AMS Survey data [9], women US citizens from underrepresented groups earned a total of 19 mathematics doctoral degrees in 2014, while White women earned 198 and Asian women earned 23. Overall, 28% of the 920 doctoral degrees awarded to US citizens that year were awarded to women. However, US women were awarded only 13.3% of all mathematics doctoral degrees awarded by US institutions that year. The difference in these numbers is a result of the fact that non-US citizens earned 52% of the mathematics doctoral degrees awarded by US institutions in 2014.

Table 20.1 compares degree awards to the prevalence of each group of women in the US population. While underrepresented women make up 15.6% of the population, they earned only 2.1% of the doctoral degrees in mathematics awarded to US citizens, and only 1% of all mathematics doctoral degrees awarded by US institutions that year.

In 2014, women earned 43% of the Bachelor's degrees in mathematics and statistics [11]. Although down from 46% some 10 years earlier the capacity for women to earn graduate degrees still remains high. Since the percentages of US mathematics

doctoral recipients in almost all categories of women in Table 20.1 are far lower than their percentage of the total US population in respective categories and much lower than their share of Bachelor's degrees, one might conclude that women of all races face barriers to persistence and completion of mathematics doctoral degrees. The data also suggest that underrepresented minorities face even greater barriers to persistence and completion than other women. In light of this, we compared EDGE PhD survey results for selected questions using two subgroups: respondents from underrepresented groups (African American/Caribbean, Hispanic/Latina, American Indian/Alaskan Native/Hawaiian) and White/European respondents.

Among respondents to the EDGE PhD Survey [3], 15 women (42%) were from underrepresented groups. The Survey results show that the EDGE-related factors contributing to the persistence of women in earning mathematics doctoral degrees differ by race. In particular:

- Women from underrepresented groups rated certain summer-session activities as “very beneficial” to their academic success more often than white women, including activities such as “working with faculty” (77% versus 47%), “interacting with guest speakers and visitors” (77% versus 21%), and “planned social activities” (85% versus 61%). White women rated the summer session academic components of the program as “very beneficial” to their academic success more often, including problem sessions (69% versus 95%) and courses (58% versus 63%).
- Women from underrepresented groups rated some post-summer-session interactions as “very beneficial” during graduate school more often than white women. These include “contact with EDGE instructors and staff” (85% versus 56%) and “continued contact with other mathematicians met through the EDGE Program” (92% versus 61%).

In general, access to a professional network was considered one of the most important benefits of the EDGE program by women of underrepresented groups.

Historically, “isolation” has been a key barrier to the success of African Americans in mathematics doctoral programs. Bozeman [2] observed that many of the early African American women enrolled in doctoral programs in mathematics lacked a peer group with whom to share ideas and problems, did not realize that others were studying as intensely as they were, and lacked access to the camaraderie and academic discourse found in study groups.

The reflections of women participants in the EDGE PhD Survey suggest a need to expand the meaning of “isolation” in departments so that it applies to the case of mathematics graduate students that have a “lack of access,” not only to the relevant peer group, but also to the culture, strategies, professional network, and all relevant information that is crucial for success in any mathematical or scientific discipline to which the student aspires.

## 20.6 EDGE Directors' Viewpoints: Developing Emerging Leaders

The impact of the EDGE Program reaches beyond its beginning graduate students. Advanced graduate student mentors in residence during the summer session gain leadership experience while juggling their own responsibilities, including exam preparation and research. These mentors often see themselves in a new, satisfying role of serving as liaisons between faculty and beginning students. From 1998 through 2013, 34 different advanced graduate students served in this role, some for multiple years. Among that group, 85% persisted to the doctoral degree. Several others from later years are still active in their graduate programs. In recognition of EDGE's commitment to diversity, half of these graduate mentors were members of underrepresented racial and ethnic groups. Some who began their association with EDGE as beginning graduate students or as graduate mentors later returned as EDGE faculty members or as local host coordinators for the summer session.

EDGE's success depends heavily on mathematics faculty who travel from their home institutions to join two-person teaching teams for the algebra and analysis summer courses. In addition to providing instruction, they collaborate with advanced graduate mentors to strengthen the program as a whole. Many solidify their connection to the EDGE community by continuing to mentor students long after the summer session ends. Through 2016, 39 different faculty members from almost as many institutions have taught the basic courses while many others offered mini-courses or gave research talks.

The EDGE leadership has provided outreach beyond the students and faculty involved in the summer sessions. For example, in response to the NSF's urgent call for "broadening participation" in its programs and activities, EDGE sponsored a national forum at the Mathematical Sciences Research Institute (MSRI) in 2008 titled, "Promoting Diversity at the Graduate Level in Mathematics." The conference served as "a call to action, a challenge, and an appeal to universities across the U.S. to address the issue of diversity in their graduate mathematics departments." By design it provided an opportunity for focused exchanges among representatives of research universities, comprehensive universities, small colleges, and graduate students. Conference Proceedings [7] containing resulting ideas and recommendations were published and are available through MSRI.

The EDGE Directors have identified numerous "EDGE Second Effects," instances of EDGE alumnae developing programs or serving in roles that support the next generation of women in mathematics. EDGE alumnae have assumed leadership roles in developing a national professional development symposium for women completing mathematics PhDs, organizing an annual mathematics and science conference for African American girls, providing a keynote speech at a national mathematics conference, serving as an AMS Congressional Fellow, delivering a mathematics-themed TED talk that has been viewed over one-million times, leading a teacher development program, assuming leadership roles in professional associations, and serving on a governor's state STEM education

task force. Further, EDGE alumnae and community members have organized special sessions at the Joint Mathematics Meetings, the Association for Women in Mathematics Research Conference, and the International Mathematics Congress in Vancouver. Many of them are also making a difference as innovative faculty members in the nation's colleges and universities. The EDGE Second Effects advance a philosophy of diversity and inclusion that is changing the composition of the next generation of mathematicians to yield greater participation by all segments of society.

The EDGE summer session is hosted at a variety of colleges and universities in order to establish a national profile among prospective students, involve local personnel throughout the country, and to more broadly engage the mathematics community. Spelman College and Bryn Mawr College hosted the first four summer sessions which were coordinated by the EDGE founders. Subsequent EDGE summer sessions (with local coordinators listed in parentheses) were held at Pomona College (Ami Radunskaya), North Carolina A&T State University (Janis Oldham), North Carolina State University (Ruth Haas, A. Loek Helminck and Kim Weems), Harvey Mudd College (Talithia Williams), Florida A & M University (Roselyn Williams), Howard University (Talitha Washington), Purdue University (Alejandra Alvarado and Edray Goins), New College in Florida (Eirini Poimenidou), and Spelman College (Fred Bowers and Yewande Olubummo). In addition to the local coordinator, each summer session benefited from the host school's support necessary to house the Program, insure the well-being of participants and visiting faculty, and meet special needs of the Program.

In 2011 Hughes and Bozeman passed the leadership of the EDGE Program to the current co-directors, Ami Radunskaya (Pomona College) and Ulrica Wilson (Morehouse College). Both Radunskaya and Wilson emerged from this evolving EDGE community of students, mentors, and faculty. Before leading the Program, Radunskaya was a member of the first analysis teaching team, taught for 11 years, and mentored scores of students. Wilson first engaged students as an advanced graduate mentor for several years and, after earning the doctoral degree, returned as an algebra instructor for five years before leading the Program. Their commitment to teaching and mentoring is woven into the EDGE program fabric. In 2014, under the leadership of Wilson and Radunskaya, EDGE reached its "50th Ph.D. milestone." In addition to creating additional support avenues for graduate students and emerging professionals, the current leadership has given oversight to the creation of The EDGE Foundation, a 501(c)(3) entity. The Foundation Board works with the co-directors to oversee program activities, including planning, marketing, development of policies and procedures, and fundraising. The goal of the Foundation is to ensure the continuation of the EDGE Program and its legacy of supporting women mathematicians.

## 20.7 Final Words: A Call to US Graduate Mathematics Departments and Thoughts on Diversity

The EDGE Program was not the first to identify and address barriers to success for women and underrepresented groups in doctoral programs in mathematics and science. In the 1998 report of her American Association for the Advancement of Science (AAAS) Presidential Lecture, *Voices from the Pipeline* [10], Sheila Widnall asserted that “a reasonable objective for the education of women and minority students is that they have a fair chance to succeed in graduate school; that the feedback loop of lowered expectations based on sex or race, leading to lowered self-image and finally to lower performance, be broken by conscious action by faculty and students.” According to the 1984–85 AMS-MAA Survey data, a few years prior to Widnall’s assertion, only 20 percent of mathematics doctoral degrees awarded to US citizens were awarded to women. None, however, were African American women that year. (A total of 7 African-American women earned mathematics doctoral degrees over the 5-year period centered on 1984–85.)

Dr. Etta Falconer, a lifetime advocate for women and minorities in science and mathematics and recipient of the Association for Women in Mathematics Louise Hay Award, among other prestigious awards, put forth her own suggestions for integrating minority students into mathematics departments. Among her many suggestions, she wrote in [5];

Graduate minority students need a proper dissertation advisor, a proper committee, the right courses, discussions of mathematics over coffee, the goodwill fostered by attending the department mathematics talks, a knowledge of actions which promote and those which retard progress, healthy research connections with faculty, help in submitting a paper to a journal, and suggestions of mathematicians to send advance copies of a research paper. In other words, they need the same things that have proven effective in moving other students into mathematics research.

The research component of the EDGE Program is a modern-day effort to build upon the work of Etta Falconer, Lee Lorch, Mary Gray, and many others who worked tirelessly for decades to diversify the mathematics and scientific communities. The voices of the women who succeeded in earning doctoral degrees while being mentored through EDGE provide guidance that directs us into the future.

Any organization external to graduate mathematics departments will be limited in effecting national change. It is, therefore, incumbent upon US graduate mathematics departments to support gender and racial diversity by adopting and adapting components of EDGE and other programs that have proven successful. The following are recommendations for US departments of mathematics that wish to diversify their graduate programs:

1. Encourage admission committees to consider personal attributes necessary for success. These attributes may include evidence of leadership, persistence, and grit, in addition to grades, and faculty recommendations. Evidence of these personal attributes may be evaluated in either academic or nonacademic settings.

2. Offer an on-location, short, intensive summer bridge program for entering mathematics graduate students. Such a program may serve students entering your program or other regional mathematics graduate programs. In the event that spots are limited, preference might be given to students from small schools with limited exposure to advanced or graduate courses. The summer bridge program may include coursework that connects undergraduate and graduate mathematics and activities that introduce students to the culture, rigor, pace, study expectations, and challenges of mathematics graduate school. The staff should include faculty and advanced graduate students, with attention to diversity.
3. Provide formal and informal mentoring and networking opportunities during and after graduate school. Graduate mathematics departments should reach out to graduate women and students from underrepresented groups to help develop professional skills that extend beyond the classroom and teaching assignments.
4. Promote a culture of agility and flexibility among mathematics graduate program faculty. This culture of agility may respond to emergent student needs, particularly among women and those from underrepresented groups.
5. Recruit and retain women faculty and faculty from underrepresented groups in the Mathematics Department. The results may model an inclusive mathematics community that offers a diverse community of role models for a diverse community of mathematics graduate and undergraduate students.
6. Design and offer activities that guard against the “isolation” of students from underrepresented groups. Help student to become integrated into their departments and also “gain access to the profession” they wish to enter.
7. Enlist advanced mathematics graduate students to mentor new mathematics graduate students. This recommendation provides not only mentoring for incoming students but also professional experience for advanced graduate students. Ensure that women and students from underrepresented groups are aware of opportunities to have mentors as well as to become mentors.
8. Work to foster a diverse community—not just a diverse collection—of mathematics faculty and students in a graduate mathematics department. This may, on occasion, require guidance from a sociologist or psychologist who is prepared to assist students and faculty in engaging in difficult dialogues.

When the EDGE Program was founded by Bozeman and Hughes to help women make the transition from college to doctoral programs in mathematics, diversity was a central goal of the participant selection process. As the Program evolved, steps were taken to ensure that EDGE had more than just diversity in numbers. Today, EDGE is a vibrant, ever-expanding, and diverse community of mathematics graduate students, doctoral recipients, and faculty that emphasizes collaboration. It enables community members to value both the comfort a community offers and the difficult conversations that sometimes ensue. EDGE today is a diverse community of individuals who mentor, advise, and collaborate across racial and cultural boundaries in ways the founders never imagined.

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