Undergraduate Mathematics:
Promising Recruitment and Retention Strategies to Ensure Diversity in the STEM Pipeline

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Honorable Chairman Hinojosa, friends, and guests, it is a special honor and privilege for me to appear before you to day to speak on a subject so critical to our nation's well-being. Student development in mathematics, science and engineering at the undergraduate level is a subject dear to my heart, and one to which I have devoted my career over the past 35 years. Thank you for the opportunity today to share in this important conversation, addressing both the need and the strategies to attract a larger segment of the US population to the study of science, engineering and mathematics.

In addressing the question, **What are the issues related to ensuring that our nation has a diverse pipeline of students into STEM, specifically undergraduate mathematics?** First, I would like to underscore **why this is an issue of such great concern.** My colleague, Professor Bressoud, has already spoken of the centrality of mathematics in relation to the other scientific fields. We must also not lose sight of the fact that **the health of mathematics at the undergraduate level is critical to the well-being of our educational system both below and above this level.** Without teachers at the high school level who have a solid mathematical content, it is difficult for our school systems to graduate students who can fuel the technical enterprises of this nation. At the upper level, our nation's colleges and universities now have large numbers of their students from African-American, Hispanic and Native American populations, but these groups make up only a small fraction of the mathematics faculties at both the high school or college levels. It is important for ALL students to see African-American, Hispanic and Native American role models in the front of the classroom, just as they need to see these groups in other professional roles and in the media. For the nation's students who are from these populations, mathematics faculty role models serve as confirmation that competence in mathematics is possible for them.

Second, I want to address the **challenges that we must face** in order to achieve strong representation in mathematics among those groups that are currently underrepresented. The situation in our nation at this point reminds me of the state of science at Spelman College in the early 1970's. Spelman College is a four-year private liberal arts Historically Black College for women in Atlanta, GA with 2100 students. In 1968, 12% of the seniors earned bachelor's degrees in science.[1] Only the truly committed chose one of the two on-campus majors of Biology and Mathematics and an occasional student pursued the Chemistry major through off-campus courses. Two African American women mathematicians had **a vision** of what could be accomplished to increase the participation of womenin the sciences--a vision of creating a more welcoming environment, new pathways into science with additional courses of study, and a nurturing environment with exposure to role models and mentors. In 1972 Dr. Etta Falconer and Dr. Shirley McBay began to convince the administration and faculty of Spelman College to join in a shared vision of producing outstanding African-American women in science. At that time they could not have predicted that their vision would lead to the National Science Foundation's designation of a "Model Institution for Excellence" in undergraduate science and mathematics education at Spelman

College in 1995. In 2007 Spelman College was one of the top two producers of African Americans in mathematics and statistics. The Chemistry Department, created in 1977, today boasts of having 46 alumnae that have earned the doctorate degree in chemistry or related fields, in addition to hundreds of other chemistry graduates.[2] Recently NSF named Spelman College as the number two baccalaureate-origin institution for African American doctoral degree recipients in science, mathematics and engineering.

The challenges that we face as a nation are very similar to the challenges faced by the administration and faculty at Spelman College in achieving their vision. Although the challenges at the national level have many more layers, they can hardly be addressed without both national and local visions and dedicated people who believe in the capacity of our nation and the ability of its students to achieve.

Locally, **broadening participation in the study of mathematics requires attention to some special challenges faced by the students in the target groups**—both because of the society in which we live and the prior education of these students. Here is a list of some challenges that must be addressed:

a. The challenge of low visibility of role models in mathematics, and other STEM areas, for students from underrepresented groups;
b. The challenge of building self-confidence and promoting a sense of belonging in science and mathematics;
c. The challenge of creating nurturing environments and supportive communities that maintain high expectations and show confidence in the ability of ALL students to achieve.
d. The challenge of meeting the financial needs of students through scholarships; and
e. The challenge of maintaining a high quality educational infrastructure at the institutions in which these students are enrolled-- including the curriculum, personnel and physical facilities.

These were very real challenges that had to be addressed by Drs. Falconer and McBay, and are still being addressed at Spelman College and at other institutions that primarily serve the populations so underrepresented in science, mathematics and engineering. They are challenges that must be confronted at the local level by the institutions of our nation that would embrace a similar vision of increasing diversity and broadening participation at the undergraduate level in their STEM programs, and specifically in undergraduate mathematics.

What are examples of effective programs that recruit and retain minority and female students into mathematics and other STEM disciplines?

Earlier I mentioned a set of challenges that must be addressed in the effort to attract and develop the mathematical interests and talents of students from underrepresented populations. Many of the programs effective in the recruitment and retention of African American students in science and mathematics are exactly those that have crafted an effective response to that set of challenges.

When students arrive at Spelman College, just as in most other colleges, few are actually planning to seriously study mathematics and many are not prepared academically to do so. In response to that reality, the College developed a collection of special programs and projects that attract and develop students in mathematics, as well as in other science disciplines. To borrow a phrase from the women

physicists who face the same reality, we must create "pathways into the discipline" for these students. Let me first describe a few strands which are common to several special programs that focus on recruitment and retention and indicate how they speak to the challenges mentioned earlier.

- First, there are **high school-to-college transition programs for students interested in science, mathematics and engineering.**

  These are used to introduce college level courses, develop study skills , introduce students to available resources and support structures, introduce role models, identify academic weaknesses, and to create potential study partners for the subsequent years. Students are able to create their own academic communities in science and mathematics—communities that support them to remain in the disciplines. At Spelman College we have found these externally funded transition programs to be an important first step to creating a pathway into the scientific disciplines for many students.

- A second commonly effective strategy is r**ecruitment by faculty and students in the Mathematics Department.**

  By recognizing the mathematical achievements of students in first-year courses and expressing confidence in their mathematical abilities, the faculty lay the groundwork for later decisions regarding a major. Consequently, women majoring in mathematics at Spelman College, include not only the few committed students who have always dreamed of studying mathematics and the double math and engineering majors, but those who had a spark of interest kindled by the positive feedback from a faculty member, as well as the undecided student looking for a home community. We understand that most African American students have never been told by anyone, "You could be a mathematician," so we tell them and then proceed to show them how they can do it. Even our student majors recruit others through the positive representation of their experiences in department.

  Allow me to illustrate with two examples. One of our recent graduates encouraged oher students during a return visit this year when she explained how unprepared she felt for the major in mathematics as she began college. Not yet ready for calculus, she began in pre-calculus. Today she holds the Ph.D. in pure mathematics from the University of Mississippi and is a college faculty member. Another student was planning to major in psychology. After a couple of mathematics courses followed by a summer research experience in mathematics, she was recruited to an interdisciplinary research team of undergraduates led by faculty in Environmental Sciences. Today she holds a Ph.D. in Biostatistics from the University of California-Berkeley and is founder of a non-profit organization devoted to science education.

- A third common element of effective programs for retention is s**trategic 'community building,'** a key to creating a sense of belonging in science and mathematics. We build community allowing students to assume leadership roles in departmental activities, to do meaningful work for the department, and by creating opportunities for them to interact with each other and with faculty in social settings. For more than 30 years our Mathematics Laboratory has served as a peer tutoring facility, now with certified tutors, offering free services. Equally important it is a place where mathematics majors strengthen their academic and professional skills by tutoring others and also hold their own informal study groups. As one recent graduate, now a college faculty member, reflected, "That was our space; we owned it and felt a commitment to the

department through it." Whatever the strategy, students who have previously been left out, must be made to feel a part of a community of mathematicians and scientists.

- Early and frequent **advising and mentoring by mathematics and science faculty** underpin a nurturing environment. In addition, a peer mentoring program has been instituted recently in the Mathematics Department which pairs upper level students with those entering the major.

- The most effective vehicle for mentoring**,** without a doubt**, is undergraduate research. I**t is one our most valuable assets in producing mathematicians and scientists among students in all populations. Students who conduct independent investigations, individually or in groups, under the guidance of faculty develop many of the research and professional skills of their mentors, and are often attracted to graduate study as a result. This close mentoring by faculty and the early introduction to research, often with a conference presentation, is even more critical for undergraduates who have not had early role models in mathematics. The experience allows them see how it feels to be a mathematician. In a sense, in the absence of role models, the students become each other's role models. Because of the very high return on this one activity the Spelman College now encourages every student to participate in research or an internship. For those who do so, we have seen a renewed sense of commitment to their studies and to the major in mathematics. Yet only a few of the REU's in this country have made this valuable experience available to significant numbers of students from underrepresented groups. In addressing this need, the Mathematical Association of America, with funding from NSF and NSA, has, for several years, provided grants to colleges to engage small groups of students from underrepresented groups in summer mathematics research on their own campuses.

- Item six on my list of recruitment and retention strategies is **scholarships integrated into special programs**. At the undergraduate level, many minority students struggle to help their families provide for their college education. We have found that scholarships and on-campus employment are critical elements in maintaining the quantity and quality of STEM majors, partially due to the long hours in study and laboratory work that are required. However, such scholarships are most effective when they are awarded in programs that combine some of the other key elements just mentioned that speak to the full development of the student.

- As a fairly recent effort, Spelman College has formalized **a college-to-graduate school transition program in mathematics,** which follows up on the long standing success of its high school-to-college transition programs. In partnership with Bryn Mawr College (Pennsylvania), it has established a national transition program for women, called Enhancing Diversity in Graduate Education, or EDGE, that has assisted more than 100 students nationally in transitioning to a graduate department. As an indication of the critical role of mentoring in mathematics, to date 36% of the first 28 doctoral recipients among its participants are African American or Hispanic women.

These are some of the key features of programs that attract and retain students in mathematics. They are effective because they give attention to the needs of students and address the challenges that these students face. In many colleges, model programs have been created that employ one or more of these common strands, woven together, and supported by external funding and creative partnerships.
As an example, one of the most effective programs of this type has been the Women in Science and Engineering Scholars Program at Spelman College, originally named the NASA WISE Scholars Program.

In 1987 the College partnered with the National Aeronautics and Space Administration (NASA) to increase the number of students earning advanced degrees in STEM disciplines. The structure of the resulting Scholars program included student scholarships, an enhanced academic curriculum, on campus mentoring and research with faculty, careful academic advising, enrichment programs, and a pre-college transition program. In addition, the students entered internships at NASA sites during the summers where they were also mentored by NASA scientists. Of these 320plus women who were WISE Scholars at Spelman College, more than half of whom have received graduate degrees, at least 40 have earned the Ph.D. degree. Today these WISE Scholar alumnae contribute throughout the academic and scientific enterprises of this nation and stand as testimony to what can be accomplished in a long term partnership with common goals for diversity.

Allow me to conclude by pointing to the high level of interest in mathematics at Spelman College that has resulted from the kinds of activities and programs described here. Today the Mathematics Department has approximately 100 African-American women majoring in mathematics and five new Ph.D. recipients in mathematics and related areas this year alone, from among recent graduates in mathematics. I offer this example of a high level of student participation in undergraduate mathematics as a testimony to the untapped potential of students of color and an indication of the under-developed resource that exists in the African American, Hispanic and Native American communities.

What is the federal role in these programs?

Our first thought is often that the federal government must provide funding, but there are many other roles that our federal agencies can play. So I will mention just two.

- **The federal government can play a significant role by promoting partnerships and collaborations that improve STEM education.** Federal policies are essential in encouraging majority institutions, federal agencies, professional organizations, and even private industries to partner with other educational institutions, particularly with HBCU's and other Minority Serving Institutions (MSIs), to strengthen STEM education and research. These partnerships can serve the two-fold purpose of strengthening the STEM infrastructure of one partner while addressing the diversity initiatives of the other. They can help all partners to better understand the resources available within the partnership and facilitate an exchange of ideas with unexpected benefits in student and institutional development. I point again to the partnership with NASA as an example. In a second example, a partnership between Spelman College and Rensselaer Polytechnic Institute (RPI), funded by NSF, to support student and faculty research in the area of nanotechnology began seven years ago. It is a partnership that developed capacity and has led to a local NSF funded project in the area of nanomaterials. The new project can be a significant resource in training more minority students in an area that is at the forefront of scientific interest.

- **Second, the many roles of the National Science Foundation are critical, including the important role that it plays in data collection and analysis.** NSF provides crucial data to use in formulating policies that address the challenges within certain populations and to gauge our progress as a nation. It was an NSF *InfoBrief* in August, 2008, that provided a list of the top baccalaureate origin institutions of 1997-2006 African American science and engineering doctorate recipients. It noted that among the top 15 producers of African American scientist and engineers, 11 are historically Black Colleges and Universities. The data point to the

significant role of undergraduate STEM education at HBCUs in producing scientists and engineers and begs the question of how the nation will support and further use this rich resource within our national education system.

- I see immediately two federal roles in funding. **Scholarship funding for students at the undergraduate level** is critical to attracting more students from lower economic levels into the study of mathematics. Last week one of my students remarked, as she was struggling to develop her skill in using a certain proof technique, "It takes a long time to do this math, but when you get it its like gold." If families are not able to pay for a college education, students who commit to mathematics and science majors are making a considerable time commitment which must be balanced with the need for part-time employment. Federal support, and federal policies that encourage private support, are essential in making these disciplines more attractive to and feasible for economically disadvantaged students.

- Beyond the direct support of students, Minority Serving Institutions(MSIs) often need what Dr. John Wilson calls **"transformational support."** In addition to scholarships, there must be support for mentoring and research programs and the entire infrastructure that is required to develop students in STEM disciplines. For example, based on the unheralded ability of the 105 HBCUs to produce scientific talent, federal funding of the scientific infrastructure of these institutions should be considered an investment in a stable commodity. Past performance shows that these institutions give a high yield in return on investments. The HBCUs enroll 10% of all African-American students yet they produce a disproportionate share of the baccalaureate degrees in science and engineering and especially in mathematics among African American students.

- HBCUs produced at the baccalaureate level 33% of the African Americans who earned doctoral degrees in science and engineering in 2006.[3] Imagine what the minority serving institutions could produce with greater federal and private investments in their science and engineering infrastructures. Imagine what they can lead the nation in doing for undergraduate mathematics through meaningful partnerships with others.

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[1] "African American Women in Chemistry: Spelman College as a National Model for Baccalaureate Degree Production" by Olivia A. Scriven and Albet N Thompson, Jr., in Models for Success, 3rd ed., Thurgood Marshall College Fund, 2009.

[2] Ibid.

[3] Role of HBCUs as Baccalaureate-Origin Institutions of Black S&E Doctorate Recipients, *InfoBrief*, National Science Foundation, NSF 08-319, August 2008.