Meeting the Challenges of Improved Post-Secondary Education in the Mathematical Sciences

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In 2012, the President's Council of Advisors on Science and Technology (PCAST), which advises President Barack Obama, issued a report, *Engage to Excel*, that raised many concerns about the teaching of the mathematical sciences in the first two years in our colleges and universities. On behalf of the Joint Policy Board for Mathematics (JPBM)—the umbrella organization of the American Mathematical Society (AMS), the American Statistical Association (ASA), the Mathematical Association of America (MAA), and the Society for Industrial and Applied Mathematics (SIAM)—David Bressoud, Eric Friedlander, and David Levermore, with support from the leadership of all four societies, crafted a response. After participation in many discussions within our professional societies, JPBM, and PCAST, we are guided in formulating the following statement. We are calling upon the entire mathematical sciences community to achieve much needed change in undergraduate education in the mathematical sciences. This statement is appearing in *AMS Notices*, *MAA Focus*, *SIAM News*, and *Amstat News*.

The mathematical sciences play a foundational and crosscutting role in enabling substantial advances across a broad array of fields: medicine, engineering, technology, biology, chemistry, computer science, social sciences, and others. The delivery of excellent post-secondary mathematics education is essential to the present and future wellbeing of our nation and its citizens.

Whereas research in the mathematical sciences is flourishing, with dramatic advances regularly occurring in core mathematics and in applications, mathematics education needs **immediate attention**. We focus on the needs of students in two-year colleges, four-year colleges, and universities. Mathematics education is a critical component of all undergraduate Science, Technology, Engineering, or Mathematics (STEM) degrees and plays a key role in educating the next generation of leaders in our increasingly technological, data-driven, and scientific society.

The President's Council of Advisors on Science and Technology (PCAST) presented many challenges to the mathematics community as it addressed the needs of post-secondary mathematics education in its 2012 report *Engage to Excel*.[1] Answering these challenges will require collaboration among all of the scientific disciplines that are working to prepare the STEM workforce of the future. We acknowledge many of the shortcomings highlighted by the report. The *wake-up call* delivered by this PCAST report has underscored the immediacy of the need for intensive, broad-scale efforts to address these problems. Whereas efforts by a great many in the mathematical sciences community predate PCAST's report, now more than ever we need a broad community-wide effort to implement innovation in all of our college and university educational programs.

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[1] www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_feb.pdf

What are these challenges, why is this an especially critical time for the mathematical sciences community, what efforts are underway to meet them, and what do we ask of the mathematical community?

Among the challenges we face is the need to find new ways to educate students who are poorly prepared for post-secondary mathematics. This includes new teaching methodologies and technology, as well as changes in curricula at all levels. We must do more to adapt the mathematics we teach to the career needs of the students we teach. We must pursue cooperation ever more energetically with mathematics-intensive disciplines. For emphasis, we rephrase these challenges as explicit questions. How should mathematics educators improve developmental education in order to enable students to aspire to STEM careers? What methods of placement and advising best help students navigate through a STEM curriculum? How should mathematical scientists in colleges and universities augment their cooperative efforts with "partner disciplines" to best serve the needs of students needing basic university mathematics? How should mathematical sciences departments reshape their curricula to suit the needs of a well-educated workforce in the twenty-first century? How can technology be best used to serve educational needs?

We are at a critical juncture. Members of the academic mathematical sciences community should recognize that *change is coming rapidly* in their world. There is great pressure to reduce costs in order to relieve state budgets and student debt; this pressure will translate to "efficiencies" and new measures of effective teaching. Numerous agencies are identifying mathematics courses as a stumbling block for success in undergraduate programs leading to a STEM degree. Increasing numbers of students coming to colleges and universities seek STEM careers that require post-secondary mathematics, yet many of these are poorly prepared. There is much demand to make mathematics education directly relevant to STEM careers.

The mathematical sciences themselves are changing as the needs of big data and the challenges of modeling complex systems reveal the limits of traditional curricula. The National Research Council report *The Mathematical Sciences in 2025*[2] eloquently describes the opportunities and challenges of this shifting landscape. This well-received report can serve as one foundation for the change that is needed, providing a springboard for initiatives in mathematics education that more closely intertwine the learning of mathematics with the appreciation of its applications.

We mention a few of the national efforts underway to address these challenges. There are many, many efforts at individual institutions that we hope will be shaped into more coherent efforts as well. For two-year colleges, the *New Mathways Project*,[3] *Statway*,[4] and *Quantway*[5] programs are assisting under-prepared students. *Project NExT*[6] is now past its twentieth year of introducing new faculty to effective strategies for teaching. MAA's national study of Calculus has identified characteristics of successful programs.[7] *Modeling Across the Curriculum*[8] is working to embed computational learning and exposure to modeling and simulation in early STEM courses. CAUSE,[9] which grew out of an ASA initiative, provides resources, professional development, outreach, and research for the needs of modern undergraduate statistics education. At research universities, there is a new program of the Association of American Universities to implement more "evidence based" teaching practices and improve the quality of teaching and learning.[10] The INGenIoUS project[11] is a joint effort of AMS, ASA, MAA, and SIAM to develop strategies for future investments in training at the graduate and undergraduate levels. Carnegie Corporation of New York and the Sloan Foundation are supporting a broad-ranging initiative entitled *Transforming Post Secondary Education in Mathematics*.[12] These efforts are steps in the right direction, but much remains to be done.

We call upon all mathematical scientists in academia to renew their focus on post-secondary mathematics education. We challenge department chairs to incentivize innovation for the sake of their students and the health of our discipline. We encourage mathematics faculty to reach out to colleagues in mathematics-intensive disciplines in order to heighten the relevance of their courses to the careers of their students. And we urge departments as a whole to investigate with an open mind new teaching methodologies and technologies, keeping in mind the need to retain and motivate students.

[2] www.nap.edu/catalog.php?record_id=15269

[3] www.utdanacenter.org/higher-education/new-mathways-project

[4] www.carnegiefoundation.org/statway

[5] www.carnegiefoundation.org/quantway

[6] archives.math.utk.edu/projnext/

[7] www.maa.org/cspcc

[8] connect.siam.org/siam-nsf-workshop-on-modeling-across-the-curriculum

[9] *Consortium for the Advancement of Undergraduate Statistics Education,* www.causeweb.org

[10] *AAU Undergraduate STEM Education Initiative,* www.aau.edu/policy/article.aspx?id=12588

[11] *Investing in the Next Generation through Innovative and Outstanding Strategies,* www.ingeniousmathstat.org

[12] tpsemath.org