A Common Vision for the Undergraduate Mathematics Program in 2025[1,2,3]

Project Overview for the
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Introduction

The primary goal of this initiative, which is funded by the National Science Foundation (NSF), is to develop a shared vision in the mathematical sciences community of the need to modernize the undergraduate mathematics program, especially the first two years. Freshman and sophomore mathematics and statistics courses function as gateways to many majors and they are crucial for preparing mathematically and scientifically literate citizens. Diverse stakeholders have made excellent, yet separate, recommendations for improving these courses. It is time for collective action to coordinate existing and future efforts in such a way that everyone is pulling in the same general direction to leverage the collective power of the whole to improve undergraduate education in the mathematical sciences.

Education in the mathematical sciences is in the national spotlight in part due to the role it plays in economic mobility. We intend to capitalize on this attention and change the public perception of mathematicians and the value and vitality of work being done in the mathematical sciences.

This initiative is titled *A Common Vision for the Undergraduate Mathematics Program in 2025*, but we will refer to it as *Common Vision* for brevity. It is intended to provide a snapshot of the current recommendations for undergraduate mathematics programs. Our activities thus far have focused on examining seven existing curriculum guides published by

[1] The project leadership team includes representation from five professional associations who focus on undergraduate mathematical sciences programs as an integral part of their mission (American Mathematical Association of Two-Year Colleges (AMATYC), American Mathematical Society (AMS), American Statistical Association (ASA), Mathematical Association of America (MAA), Society of Industrial and Applied Mathematics (SIAM)): Karen Saxe (Principal Investigator, Macalester College), Linda Braddy (co-PI, MAA), John Bailer (Miami University), Rob Farinelli (College of Southern Maryland), Tara Holm (Cornell University), Vilma Mesa (University of Michigan), Uri Treisman (University of Texas at Austin and Charles A. Dana Center for Innovation in Math and Science Education), and Peter Turner (Clarkson University). Affiliations are for identification purposes only and do not imply an institution's endorsement of this document.

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[3] For more information contact project PI Karen Saxe at saxe@macalester.edu or co-PI Linda Braddy at lbraddy@maa.org

mathematical sciences professional associations and highlighting the common themes found in these guides. This initiative will also lay a foundation for future work that acknowledges the changing face of the mathematical sciences, particularly with respect to the inclusion of data science, computation, statistics, and modeling. We are working to incrementally strengthen curriculum to better reflect the mathematical sciences as they are today and help leadership understand the trade-offs that can be made in shaping undergraduate programs.

Assumptions

Our assumptions are:

1. Mathematical scientists – including mathematicians, applied mathematicians, statisticians, computer scientists, and mathematical sciences educators – can contribute to scientific initiatives outlined by the Office of Science and Technology Policy to advance national priorities that are in the best interests of all citizens.

2. The most productive approach to preparing the next generation of citizens literate in Science, Technology, Engineering, and Mathematics (STEM) will involve multidisciplinary teams of mathematical scientists and domain specialists from STEM and non-STEM fields working together to modernize the undergraduate mathematics program.

3. Mathematical sciences courses in the first two years of college function as pathways into many different STEM majors and also serve as key components in the preparation of scientifically literate citizens.

Impetus to change

We are responding to national calls to action to improve undergraduate training in mathematics and statistics. These calls include, but are not limited to, *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics* (President's Council of Advisors on Science and Technology, 2012) and *The Mathematical Sciences in 2025* (National Research Council, 2013). These two recent reports criticize our collective enterprise of teaching undergraduate mathematics.

We are also responding to the fact that the environment for learning and teaching mathematics in higher education has undergone and continues to experience significant changes.

Changes are particularly profound in the areas of:

– Student preparedness and diversity.

– Student career goals and the need for workplace skills (e.g., technology skills, data analysis skills).

– Quantitative skills demanded by more disciplines including, for example, the social sciences.

– Advances in technology (e.g., software for teaching, learning, and assessment; massive open online courses (MOOCs)).

– State budget cuts for post-secondary education.

– Shifts in states' funding priorities from funding based on enrollment to funding based on completion.

In *The Mathematical Sciences in 2025*, the National Research Council (NRC) calls for mathematics departments to rethink the types of students they are attracting and wish to attract at all levels and to identify the top priorities for educating these students. The expansion of research opportunities in the mathematical sciences provides additional impetus to rethink the way students are prepared and how to attract more students into the discipline. Change is unquestionably coming to lower-division undergraduate mathematics, and it is incumbent on the mathematical sciences community to ensure that it is at the center of these changes and not on the periphery.

In their *Engage to Excel* report, the President's Council of Advisors on Science and Technology (PCAST) acknowledges that fewer than 40 percent of students who enter college intending to major in a STEM field actually go on to complete such a degree. They conclude that retaining more STEM majors is the best option for addressing the inadequate supply of STEM professionals in the United States workforce. An additional aspect of the retention challenge is retaining underrepresented groups (non-Asian minorities and women) in mathematical sciences degree programs at all levels, undergraduate through doctoral.

Our community recognizes that many students encounter significant barriers along the traditional route to a STEM career and thus graduate with inadequate mathematical competencies as they enter the United States workforce. *The Mathematical Sciences in 2025* (NRC, 2013) suggests that we reassess the training of future generations of mathematical scientists in light of the increasingly cross-disciplinary nature of the STEM fields. Substantial efforts have been undertaken to help us understand the challenges; indeed, promising curricular updates and pedagogical practices have been recommended. However, few such practices are being implemented at a scale necessary to make a significant impact on the number of mathematics graduates entering the workforce, the number of students pursuing a degree in mathematics, or the number of graduates in all fields who have adequate mathematics skills and competencies to meet current workforce demands. Facilitating multiple pathways requires a well-coordinated effort of multiple stakeholders, including faculty, higher education administrators, employers, professional associations, and funding agencies. By bringing together thought leaders from these various sectors, *Common Vision* will ultimately serve to catalyze widespread adoption of modernized curricula and pedagogies.

The collective enterprise of teaching

Research on "collective impact" (Kania and Kramer, 2011) suggests that, in achieving significant and lasting change in any area, a coordinated effort supported by major players from all existing sectors is more effective than an array of new initiatives and organizations. This initiative encourages such action by highlighting existing efforts and draws on the collective wisdom of a diverse group of stakeholders to articulate a shared vision for modernizing the undergraduate mathematics program.

It is thus critical to the success of this project that we have participation from a broad range of professional associations. The Conference Board of the Mathematical Sciences (CBMS) is an umbrella organization consisting of seventeen professional associations, all of which have as one of their primary objectives the increase or diffusion of knowledge in one or more of the mathematical sciences. Five of the seventeen – the American Mathematical Association of Two-Year Colleges (AMATYC), the American Mathematical Society (AMS), the American Statistical Association (ASA), the Mathematical Association of America (MAA), and the Society of Industrial and Applied Mathematics (SIAM) – focus on undergraduate teaching to some degree. Project leaders have thus been drawn from the AMATYC, AMS, ASA, MAA, and SIAM.

AMATYC. The American Mathematical Association of Two-Year Colleges (AMATYC), founded in 1974, is the only organization exclusively devoted to providing a national forum for the improvement of mathematics instruction in the first two years of college. Central to its mission are promoting and increasing awareness of the role of two-year colleges in mathematics education, and communicating the perspectives of two-year college mathematics educators to public, business, and professional sectors. AMATYC has approximately 1,800 individual members and more than 150 institutional members in the United States and Canada.

AMS. The American Mathematical Society (AMS) was founded in 1888 to further the interests of mathematical research and scholarship. Through its publications, meetings, advocacy, and other programs, the AMS supports mathematics education at all levels and fosters an awareness and appreciation of mathematics and its connections to other disciplines and everyday life. Members include almost 30,000 individuals and 580 institutional members worldwide.

ASA. The American Statistical Association (ASA) is the world's largest community of statisticians, the "Big Tent for Statistics." The ASA supports excellence in the development, application, and dissemination of statistical science through meetings, publications, membership services, education, accreditation, and advocacy. Founded in 1839, the ASA is the second-oldest continuously operating professional association in the country. Since its inception, the association has had a close affiliation with the statistical work of the United States government, particularly the Bureau of the Census. Today, the ASA serves 18,000 members worldwide.

MAA. The Mathematical Association of America (MAA) is the largest professional association that focuses on mathematics accessible at the undergraduate level. Members include university, college, and high school teachers; graduate and undergraduate students; pure and applied mathematicians; computer scientists; statisticians; and many others in academia, government, business, and industry. The mission of the MAA is to advance the mathematical sciences, especially at the collegiate level. The MAA was established in 1915 and currently serves 17,000 individual and institutional members worldwide.

SIAM. Incorporated in 1952, the Society for Industrial and Applied Mathematics (SIAM) is an international community of over 13,000 individual members. Almost 500 academic, manufacturing, research and development, service and consulting, government, and military organizations worldwide are institutional members. Through publications, research, and community, SIAM pursues its mission to build cooperation between mathematics and the worlds of science and technology. SIAM's goals are to advance the application of mathematics and computational science to engineering, industry, science, and society; promote research that will lead to effective new mathematical and computational methods and techniques for science, engineering, industry, and society; and provide media for the exchange of information and ideas among mathematicians, engineers, and scientists.

Phase I: Common Themes

Phase I of our two-part initiative focuses on introspection. Many publications have guided our thinking, and we have chosen seven curricular guides on which to focus. Each of these seven guides is a major enterprise endorsed by the supporting association.

- *Beyond Crossroads*, released in 2006, is AMATYC's update of the 1995 publication *Crossroads in Mathematics: Standards for Introductory College Mathematics Before Calculus.* http://beyondcrossroads.matyc.org/

- *Guidelines for Assessment and Instruction in Statistics Education College Report* is the ASA's 2012 publication with recommendations for introductory statistics curricula. The ASA's Guidelines for Assessment and Instruction in Statistics Education (GAISE) project consisted of two groups focused on K-12 education and introductory college courses, respectively. This publication presents the recommendations developed by the college-focused group. http://www.amstat.org/education/gaise/

- *Guidelines for Undergraduate Programs in Statistical Science*. These guidelines were endorsed by the ASA board of directors in 2014. http://www.amstat.org/education/curriculumguidelines.cfm

- The *Committee on the Undergraduate Program in Mathematics Curriculum Guide*. The MAA's Committee on the Undergraduate Program in Mathematics (CUPM) is charged with making recommendations to guide mathematics departments in designing curricula for their undergraduate students. CUPM began issuing guidelines in 1953, updating them at roughly ten-year intervals. Printed copies of the newest guide will be distributed in early 2015 and the online guide is available at http://www2.kenyon.edu/Depts/Math/schumacherc/public_html/Professional/CUPM/2015Guide/CUPMDraft.html

- *Partner Discipline Recommendations for Introductory College Mathematics and the Implications for College Algebra*. Curriculum Renewal Across the First Two Years (CRAFTY) is a subcommittee of CUPM and is charged with monitoring ongoing developments in curricula for the first two years of college mathematics and making general recommendations. This guide was completed in 2012. http://www.maa.org/sites/default/files/pdf/CUPM/crafty/introreport.pdf

- *Modeling across the Curriculum*. This SIAM guide provides a summary of the first Modeling across the Curriculum workshop held in 2012 and makes recommendations on curricula in areas relevant to applied and computational mathematics. The second such workshop was held in January 2014, and the associated report is currently being prepared (December 2014). http://www.siam.org/reports/modeling_12.pdf

- *Undergraduate Programs in Applied Mathematics* was released by SIAM in 2014. http://www.siam.org/reports/undergraduate_14.pdf

Common Vision will involve a two-and-a-half-day workshop for over fifty participants held in May 2015 at the ASA headquarters in the Washington, DC area. Participants will represent the five aforementioned mathematical sciences associations as well as partner STEM disciplines and industry.

Phase I of the *Common Vision* initiative will conclude with a report in fall 2015 articulating the commonalities found in these seven curricular guides. We classify these common themes into four interdependent categories: curricula, workforce training, pedagogies, and faculty development.

Curricula

Courses taught at colleges and universities during the first two years range from remedial courses to advanced calculus and differential equations, and our focus is the collection of credit-bearing mathematics courses a student might take in the first two years. We examine the undergraduate program using a wide-angle lens, inclusive of modeling, statistics, and computational mathematics as well as applications in the broader mathematically based sciences.

All seven of the guides call for offering alternate pathways into and through the mathematical sciences curriculum, including early exposure to statistics, modeling, and computation. Data-driven science is reshaping discovery and learning in the 21st century. The current attention to big data and the need for college graduates with data skills should prompt changes in our entry-level courses and result in students better prepared for jobs requiring computer science and statistics skills. Attention on the calculus sequence and pathways to it must remain a high priority, as calculus is central to all further work in the mathematical sciences.

Throughout the guides, we see the call for more attention to the needs of other disciplines. All guides recommend employing a broad range of classic and contemporary applications to motivate the mathematics, promote awareness of connections to other subjects, strengthen each student's ability to apply the course material, and enhance student perceptions of the relevance of mathematics to the modern world.

Workforce training

Mathematical sciences courses serve as key components in the preparation of a mathematically and scientifically literate workforce. While we acknowledge there is no "one-size-fits-all" solution, we must develop structures to catalyze widespread adoption of curricula and evidence-based pedagogies that are (1) geared toward developing a broad base of intellectual skills and competencies to better prepare students for the workforce and (2) endorsed by the mathematical sciences community.

Mathematics departments play a major role in preparing the workforce. In response to workforce needs, departments should establish advisory committees that include representatives from business, industry, and government to regularly engage in conversations about the expectations of prospective employers. Departments must find partners from inside and outside academia from STEM and non-STEM fields to ensure that the applications we teach are realistic, and that the skills our students take from our courses are valued by stakeholders. We must prepare graduates who are career-ready. Even in the first two years of college we must offer students opportunities to improve their speaking and writing skills, to work with data, and to engage in open-ended inquiry. Data skills, in particular, are increasingly attractive to employers. According to *Fueling Innovation and Discovery* (NRC, 2012):

> The mathematical sciences contribute to modern life whenever data must be analyzed or when computational modeling and simulation is used to enable design and analysis of systems or exploration of "what-if" scenarios. The emergence of truly massive data sets across most fields of science and engineering, and in business, government, and national security, increases the need for new tools from the mathematical sciences.

STEM and non-STEM graduates with marketable skills contribute to the "common good," by advancing national priorities that are in the best interests of all citizens. Mathematical competencies also lead to higher-paying career opportunities and, thus, can play a profound role in students' economic mobility (Haskins, Holzer, and Lerman, 2009).

Pedagogies

Across the guides we find a general call to move away from the use of traditional lectures as the sole instructional delivery method for undergraduate mathematics courses. All guides stress the importance of moving toward environments that incorporate multiple pedagogical approaches throughout a program. One oft-cited example of a preferred technique is active learning, a process whereby students engage in activities such as reading, writing, discussion, or problem solving that promote analysis, synthesis, and evaluation of class content. Cooperative learning, problem-based learning, and the use of case methods and simulations are also approaches that actively engage students in the learning process. These types of pedagogies promote collaboration and offer practice communicating the subject. A multifaceted approach to instruction is important for teaching students to be flexible in the ways they process information. The use of these diverse instructional approaches should be a strategic part of the curriculum.

Pedagogical innovations are often driven by advancing technologies. Students need to learn to use technology appropriately; they need to become intelligent consumers of the answers technology provides. Technology in the classroom can be used for developing conceptual understanding, analyzing data, and as a tool for solving problems. It can strengthen students' problem-solving skills by encouraging them to utilize multiple strategies (graphical, numerical, algebraic). Data sets available on the Internet provide opportunities to address problems rooted in real data. Technology can be especially valuable in helping students think conceptually and algorithmically.

Technology can be used not only to strengthen teaching and learning in the classroom but also to control costs in education.

Faculty development

It is no surprise that support for faculty development is highlighted in all the guides. The ASA's *Guidelines for Undergraduate Programs in Statistical Science* articulates the need in this way:

> A considerable barrier to implementing these guidelines is the lack of materials related to data science topics. Efforts to pull together activities, projects, sample syllabi, and model courses as well as training are needed to ensure that faculty have the appropriate skills to teach aspects of this new curriculum.

Pressing issues

There are a number of topics addressed in some of the guides that we view as critical for improving undergraduate mathematical sciences education even though they did not appear on **all** the guides:

- Issues of diversity related to women and minorities in STEM. According to the CUPM 2015 curriculum guide:

  > Minority students and women who start below the standard entrance point (calculus) for majors may be particularly reluctant to continue in mathematics. . . . Even when a curriculum is structured to allow alternative entry points to the major, many students need advisors, coaches, professors, and peers to help clear the way.

  The fact that we have not been able to attract and retain a diverse student body in the mathematical sciences is a dreadful shortcoming that must be addressed.

- The large number of adjunct and other contingent faculty currently teaching our courses. Non-tenure-track positions of all types now account for 76 percent of all instructional staff appointments in American higher education (AAUP, n.d.). The various challenges these faculty members face and strategies to address their professional development are discussed in *Beyond Crossroads* (AMATYC, 2006).

- Issues of scaling and long-term sustainability. Curricular and pedagogical initiatives must be team efforts, with faculty in supporting roles who can be prepared to take over the leadership roles. Many past efforts and programs have not survived the founders leaving, retiring, or burning out. Mathematical sciences departments and institutional administrators should encourage, support and reward faculty efforts to improve the efficacy of teaching and strengthen curricula. *Modeling across the Curriculum* (SIAM, 2012) and the CUPM 2015 curriculum guide discuss the role of faculty and faculty supports in this context of scaling and sustaining initiatives.

- The changes that states are making in the K-12 curriculum. Articulation issues are discussed in the CUPM 2015 curriculum guide, in *Beyond Crossroads* (AMATYC, 2006), and in the *Guidelines for Undergraduate Programs in Statistical Science* (ASA, 2014). In particular, we must provide clear pathways between curricula driven by the Common Core State Standards in Mathematics (CCSSM, 2010) and the first courses students take in college.

- The critical role played by the publishing industry and other suppliers of curricular resources, as discussed by *Beyond Crossroads* (AMATYC, 2006) and *Modeling across the Curriculum* (SIAM, 2012). Faculty can collaborate with publishers to translate research into practice and produce evidence-based instructional materials.

- The high rate of failure in post-secondary mathematics courses and its contribution to increased attrition rates and time to degree. Mathematics courses are generally considered the most significant barrier to college success. For example, each year approximately 50 percent of students fail to pass college algebra with a grade of C or better, and fewer than 10 precent of the students who pass this class enroll in a rigorous calculus course (CRAFTY, 2012). The high failure rate points to the need for enhanced student supports to help students persevere and improve their ability and confidence to use mathematics to solve problems.

Phase II: Moving Forward

Phase II of *Common Vision* will be an outward-looking period focused on widespread dissemination and implementation of modernized curricula and delivery methods.

Given the importance of the mathematical sciences in solving problems of national importance, we propose to establish a *Center for the Advancement of Mathematical Sciences Education* (CAMSE) to support improving teaching and learning in undergraduate mathematical sciences courses. This Center will be modeled after the NSF mathematical sciences institutes. Such a structure will facilitate adaptation, implementation, and scaling efforts.

The core focus of the Center will be assisting departments and institutions in rethinking curricula and pedagogies. The mission of the Center will be to facilitate implementation of evidence-based strategies in order to:

- Increase the number of students who obtain STEM degrees, thus expanding the pool of STEM graduates who are well-prepared for the workforce or further study in the mathematical sciences.
- Broaden participation in the mathematical sciences.
- Strengthen STEM competencies of all students, including non-STEM majors.

The Center will pursue its mission through a variety of strategies:

- Implement communications strategies to engage the mathematical sciences community in the quest to improve undergraduate instruction.
- Lead efforts to identify key elements of successful undergraduate mathematical sciences programs.
- Assist departments with implementing initiatives to improve student success.
- Create and maintain a database of programs and initiatives that have demonstrated potential for increasing student success.
- Foster activities (e.g., special sessions, panel discussions, plenary talks) at professional conferences that focus on the mathematical training of STEM majors.
- Communicate (through, e.g., workshops and conferences) with other STEM disciplinary associations and higher-ed associations to better serve partner disciplines.
- Publish white papers on issues surrounding undergraduate mathematics education for STEM and non-STEM fields to be distributed to stakeholders.
- Work with funding agencies to identify new opportunities and build on existing efforts.

References

American Association of University Professors (AAUP) (n.d.). *Background Facts on Contingent Faculty*. Retrieved from website: http://www.aaup.org/issues/contingency/background-facts. Accessed November 2014.

American Mathematical Association of Two-Year Colleges (2006). *Beyond Crossroads*. Retrieved from American Mathematical Association of Two-Year Colleges website: http://beyondcrossroads.matyc.org/. Accessed November 2014.

American Statistical Association (2012). *Guidelines for Assessment and Instruction in Statistics Education College Report*. Retrieved from American Statistical Association website: http://www.amstat.org/education/gaise/. Accessed November 2014.

American Statistical Association (2014). *Discovery with Data: Leveraging Statistics with Computer Science to Transform Science and Society*. Retrieved from American Statistical Association website: http://www.amstat.org/policy/pdfs/BigDataStatisticsJune2014.pdf. Accessed November 2014.

American Statistical Association (2014). *Guidelines for Undergraduate Programs in Statistical Science*. Retrieved from American Statistical Association website: http://www.amstat.org/education/pdfs/guidelines2014-11-15.pdf. Accessed November 2014.

Blair, R., Kirkman, E.E., and Maxwell, J.M. (2013). *Conference Board of Mathematical Sciences (CBMS) Survey Reports 2010*, Washington, DC: American Mathematical Society.

Carnevale, A. P., Smith, N., and Melton, M. (2011). *STEM: Science, Technology, Engineering, Mathematics*, Washington, DC: Georgetown University Center on Education and the Workforce.

Center for Research on Learning and Teaching at the University of Michigan (n.d.). *Active Learning*. Retrieved from University of Michigan website: http://www.crlt.umich.edu/tstrategies/tsal. Accessed November 2014.

Chen, X. (2013). *STEM Attrition: College Students' Paths Into and Out of STEM Fields (NCES 2014-001)*. Washington, DC: National Center for Education Statistics, Institute of Education Sciences, United States Department of Education.

National Governors Association and The Council of Chief State School Officers. (2010) *Common Core State Standards for Mathematics (CCSSM)*. Washington, DC: Retrieved from Common Core State Standards Initiative website: http://www.corestandards.org/assets/CCSSI_Math%20Standards.pdf. Accessed November 2014.

The Dana Center, Jobs for the Future, Complete College America, and Education Commission of the States (2012). *Core Principles for Transforming Remedial Education: A Joint Statement*. Retrieved from The Dana Center at the University of Texas at Austin website: http://www.utdanacenter.org/. Accessed November 2014.

The Dana Center (2014). *Transforming Post-Secondary Education in Mathematics: Report of a Meeting*. Retrieved from Transforming Post-Secondary Education in Mathematics at the University of Texas at Austin website: http://www.tpsemath.org/. Accessed

December 2014.

Haskins, R., Holzer, H., and Lerman, R. (2009). *Promoting Economic Mobility by Increasing Postsecondary Education*. Retrieved from The Pew Charitable Trusts website: http://www.pewtrusts.org/. Accessed November 2014.

Holdren, J. P., and Lander, E. S. (2012). *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*. Washington, DC: PCAST Report to the President.

Kania, J. and Kramer, M. (2011). *Collective Impact*, Stanford Social Innovation Review, Winter 2011.

Mathematical Association of America (2012). *Partner Discipline Recommendations for Introductory College Mathematics and the Implications for College Algebra*. Retrieved from Mathematical Association of America website http://www.maa.org/sites/default/files/pdf/CUPM/crafty/introreport.pdf. Accessed November 2014.

Mathematical Association of America (to appear 2015). *Committee on the Undergraduate Program in Mathematics Curriculum Guide 2015*. Retrieved from: http://www2.kenyon.edu/Depts/Math/schumacherc/public_html/Professional/CUPM/2015Guide/CUPMDraft.html. Accessed November 2014.

National Research Council (2012). *Fueling Innovation and Discovery: The Mathematical Sciences in the 21st Century*. Washington, DC: The National Academies Press.

National Research Council (2013). *The Mathematical Sciences in 2025*. Washington, DC: The National Academies Press.

Office of Science and Technology Policy (n.d.). *OSTP Initiatives*. Retrieved from Office of Science and Technology Policy website: http://www.whitehouse.gov/administration/eop/ostp/initiatives. Accessed November 2014.

Office of Science and Technology Policy (n.d.) *Big Data is a Big Deal*. Retrieved from Office of Science and Technology Policy website: http://www.whitehouse.gov/blog/2012/03/29/big-data-big-deal. Accessed November 2014.

Pierson, S. (2013). *Undergraduate Statistics Degrees Continue Large Increases in 2012*. AMSTATNEWS, October 1, 2013. Alexandria, VA: American Statistical Association.

Pierson, S. (2014). *Statistical Scientists Advance Federal Research Initiatives*. AMSTATNEWS, July 1, 2014. Alexandria, VA: American Statistical Association.

Society for Industrial and Applied Mathematics (2012). *Modeling across the Curriculum*. Retrieved from Society for Industrial and Applied Mathematics website: http://www.siam.org/reports/modeling_12.pdf. Accessed November 2014.

Society for Industrial and Applied Mathematics (2014). *Undergraduate Programs in Applied Mathematics*. Retrieved from Society for Industrial and Applied Mathematics website: http://www.siam.org/reports/undergraduate_14.pdf. Accessed November 2014.

Zorn, P., Bailer, J., Braddy, L., Carpenter, J., Jaco, W., and Turner, P. (2014). *The INGenIOuS Project: Mathematics, Statistics, and Preparing the 21st Century Workforce.* Washington, DC: Mathematical Association of America.