



Report of a Workshop
Joint Mathematics Meetings
San Antonio, Texas

January 10, 2015

Introduction

Transforming Post-Secondary Education in Mathematics (TPSE Math) is a voluntary effort led by a small group of concerned mathematicians who share a belief that significant reform is needed in mathematics teaching and learning in American post-secondary institutions.¹

TPSE Math convened an informal two-hour workshop at the Joint Mathematics Meetings in San Antonio, Texas in January 2015, which is summarized below. This followed a similar workshop at the 2014 JMM in Baltimore, Maryland; a three-day, national-scale meeting at the University of Texas at Austin in June 2014; and a regional meeting at the University of Maryland, Baltimore County in November 2014. Reports on the Texas and Maryland meetings, as well as videos and PowerPoint presentations, are available at www.tpsemath.org/.

The challenges facing mathematics education include the critical need for more effective developmental courses, new demands on math's service mission to fast-changing STEM and non-STEM disciplines, poor coordination among institutions of different levels, and severe financial pressures on public institutions. Many individuals and organizations have recognized these challenges are developing innovative responses.

The San Antonio meeting, along with TPSE Math itself, have been organized to hear from some of the organizations most active in understanding and responding to these challenges, and to build stronger coordination that will be needed to scale up successful reforms in a coherent way. The following is a summary of the attendees' presentations, which, taken together, provide a summary of themes and issues of highest concern to the nation's leading mathematics organizations.

Paul Zorn, St. Olaf College; Mathematical Association of America (MAA)

Dr. Zorn began by summarizing the goals of the INGenIOuS project (Investing in the Next Generation through Innovative and Outstanding Strategies), whose "main purpose is to focus on the workforce preparation aspects of mathematics education at all levels." The INGenIOuS project is a collaborative effort by the AMS, ASA, MAA, SIAM, and NSF. It was founded, he said, "with the aim of advising NSF on strategies for supporting better workforce preparation." A summer workshop in 2013 focused on describing existing and proposing new workforce development strategies and projects. Various metrics to gauge the success of such strategies were proposed by participants and are described, along with projects themselves, in the workshop report.

¹ Current members of TPSE Math are Phillip A. Griffiths, Institute for Advanced Study, Convener; Eric Friedlander, University of Southern California; S. James Gates, Jr., University of Maryland; Mark Green, University of California Los Angeles; Tara Holm, Cornell University; and Uri Treisman, University of Texas at Austin.

Donald McClure, American Mathematical Society (AMS)

Dr. McClure described a series of “targeted public awareness efforts” made by the AMS, including Math Moments, posters published with the goal of making high school students aware of what they can do with mathematics; the Annual Award for Impact on Teaching and Learning Mathematics, celebrating contributions by mathematicians to improving the math education of students in the first two years of college; and a new blog on Teaching and Learning Mathematics, including a series of mathematics education in partnership with the CBMS. The AMS Committee on Education also invites department chairs to its annual meetings, where the emphasis now is on undergraduate education. The AMS topic at the JMM for 2015 was Active Learning Strategies for Mathematics.

Ron Rosier, Conference Board of the Mathematical Sciences (CBMS)

To illustrate the lean structures behind some of the nation’s mathematics organizations, Dr. Rosier introduced himself as “half the staff” of the CBMS. He acknowledged the lack of coherence in the infrastructure of the community, but noted the “raging agreement” (notably in the Common Vision report described below) that actions and ambitions of the mathematics community should and must be strengthened. The Ingenious report, he said, “was something all the societies wanted to get behind – the problem is how do the societies cooperate with and support each other. All the presidents are eager to do that, but are still searching for the best way to work together toward a very positive outcome.”

Francis Su, Harvey Mudd College; MAA

Dr. Su said that undergraduate mathematics had “always been at the fore of what the MAA does” because it’s tied to the MAA mission. It has long been active in promoting high-quality teaching and supporting undergraduate education. He highlighted the work of the Common Vision, the Ingenious project, NSF grants to MAA to study successful calculus programs, and the CUPM effort that has mobilized more than 250 mathematicians to write a report with recommendations about the undergraduate curriculum.

One initiative he emphasized as a “shining example of what the MAA is doing” is its support for “faculty new to the profession” under Project NExT, which stands for New Experiences in Teaching. “At least 1,500 people have gone through this program,” he said, “and are now in positions of leadership. The program trains faculty to think carefully about undergraduate education, and offers opportunities to learn new ways of teaching. It also helps us think through adapting to the culture of faculty life while pushing the boundaries of what people think is possible in teaching.” He highlighted the importance of reaching underrepresented groups and the MAA’s and Project NExT’s attention to this area.

He also reminded the group that many active members of the math organizations are members of multiple societies, so there is a natural capacity for cooperation between societies on many issues.

Joan Ferrini-Mundy, Education and Human Resources (EHR), National Science Foundation

Dr. Ferrini-Mundy, who has long been a leader in mathematics education, began by saying that undergraduate education is currently a “critical topic for the government.” She cited the PCAST report, and recent NSF calls for proposals in mathematics focused on the first two undergraduate years. “It’s a piece of a much bigger set of national issues,” she said. “Having a group trying to figure out how to work on it and come together is timed perfectly.”

She also noted the central importance of coherence and scale. With scale, she said, “be careful about what we would like to have happen, and think about impact. Do we really see improvements in

retention? professional goals? proficiency? staying in STEM fields and mathematics?” She offered “a bit of caution” about the effectiveness of evaluation, saying that it would be very difficult to get federal or foundation support unless the results are clear. “Keep thinking about connecting all those dots,” she said; “how to argue that a particular kind of approach or intervention can give us evidence of actual impact. From the educational perspective at NSF, we’re watching this with a lot of interest.”

Uri Treisman, University of Texas at Austin

Prof. Treisman followed up the discussion of scale by noting that “questions of scale and quality are on the minds of chairmen, but many don’t have the most basic tools to answer elementary questions about the effects of their program. When they look at the standards wanted by foundations and government, the standards of evidence have gone up so much that math chairs look at it and are overwhelmed. How do we produce a set of simple tools that a responsible chair can use? It’s remarkable how many haven’t had enough basic data on their own performance.”

What matters even more, he added, is legitimizing assertions about performance. “What the professional societies signal to their constituents is what we should be doing. But as soon as they start working on scale, more is needed. [We want to take] Project NeXT and some of the beautiful things we’re already doing but don’t have sufficient infrastructure: How do we build tools to enable those things to realize their full potential? We need to be able to answer as mathematicians should: We have evidence! We’ve looked at the numbers!”

Nancy Sattler, American Mathematical Association of Two-Year Colleges (AMATYC)

Dr. Sattler introduced AMATYC as “the only national organization that focuses on the first two years of college teaching,” and listed a number of activities. She praised Project ACCESS (Advancing Community College Careers: Education, Scholarship, Service), which provides mentoring and professional development for new teachers, and described an important goal as collaboration with other societies in providing pre-requisite courses to help prepare students to be mathematics teachers. One such example is partnering with the Association of Mathematics Teacher Educators (AMTE) to seek out grant opportunities.

Some of the group’s work is designed to provide alternative pathways through mathematics, including those not leading to calculus, “which is huge for us.” In November, the AMATYC delegate assembly passed a position statement which mentions that prerequisite courses other than intermediate algebra can adequately prepare students for courses of study that do not lead to calculus.

The group also works closely with the Dana Center at the University of Texas at Austin, and has created a position statement on textbooks and instructional materials, with the help of its “Innovative Teaching and Learning Committee.” She concluded by saying that “our position papers are used at the college level to prove a point,” and “I think community colleges are really coming into being.”

Martha J. Siegel, Towson University; MAA Committee on the Undergraduate Program in Mathematics (CUPM)

Professor Siegel said that at her public university about 50% of students majoring in mathematics come from community colleges, many of them unprepared for university-level mathematics. She described this as a serious issue: “How are we going to work this out? It is an issue that the CUPM discusses regularly. I think it’s largely a state issue. Rather than being forced to do certain things, it would be nice if regional groups got together to work on this. This has been going on for a long time in Maryland, and was totally spontaneous.” She said that a group headed by Denny Gulick at the University of Maryland

at College Park meets at least once each semester to discuss undergraduate education issues.

One major change in Towson's undergraduate program has been a new major in statistics, which supplements its traditional major in the mathematical sciences. "The number of statistic majors has gone sky-high," she said. "We have to retrain people to teach it at the first two years, and those who teach the first two years of mathematics – everything but calculus – are almost all adjuncts. They don't have opportunities for the professional development we think might be important to them, and we don't have the resources for helping them do what we think is important. We have good control of the TAs, but not people who are coming in to teach one course."

Overall, she said, CUPM has "tried hard to get everyone's opinion," noting that "if we're not teaching the first two years successfully, we're not going to have a math department."

David Levermore, University of Maryland

Dr. Levermore said he would like to issue "a call for paying attention to the communities not represented at this table." He said that being chair of the Board on Mathematical Sciences and Their Applications at the National Academies for six years "gave me a whole new perspective on the national conversation on STEM education." We need industries at the table, he said, and computer scientists, and many others.

"This huge change is affecting many disciplines. In Washington literally every month a board is convened, often at the NRC, discussing STEM ed. I know some of our societies make an effort to go – MAA, SIAM – but we have to be at more of those conversations. There are many more now than there were 10 years ago, and this is a game changer. The computer community is always there, but if we're not there and speaking up, our voice is lost. I encourage us to step out of our comfort zone and sit down with engineers who are pushing their case in an active way."

He said he had been at meetings where, for example, computer scientists favored replacing the first two years of mathematics with courses in "computer literacy." Or he would listen as computer scientists "duked it out with statisticians about how to teach big data," and he was the only mathematician there. "We have to step up and be aware of these conversations. Our community cared about education long before those other communities, so we got very used to being a strong voice. But now these other communities care with a passion, and they have big voices in Washington."

Diane J. Briars, National Council of Teachers of Mathematics (NCTM)

Dr. Briars said that the K-12 community was greatly "encouraged by these conversations, the recommendations you're coming up with, and the directions you're talking about. These are things we want to support."

She said that current dialogues were transformational "in terms of changing what's going on, especially in middle school and high school mathematics, in terms of better preparing students and really understanding mathematics, instead of racing through and picking up a lot of skills but missing the deep understanding they need. We are very encouraged."

Karen Saxe, Macalester College; Common Vision Project, MAA

Dr. Saxe said that the Common Vision Project included five of the 17 organizations of CBMS, all of which had missions that included, at least in part, undergraduate education: AMATYC, AMS, ASA, MAA, and SIAM. Among the many issues the project highlights are the widespread shift from using enrollment

figures to calculate state budget allocations to higher education institutions to using completion rates. Many of the states' new allocation requirements point to increasing STEM degrees as a goal, or in some other measure of success with STEM students. Another is the widespread opinion that mathematics is "the main barrier to college completion," which would clearly be a problem if trying to graduate more STEM majors. "I think we need to do much more outreach to the state governments, along with the federal government."

Rachel Levy, Harvey Mudd College; SIAM

The first program described by Dr. Levy was Modeling Across the Curriculum, a SIAM effort funded by NSF. It was built around the idea that modeling can build many job skills students need and can be an important educational tool at not only the secondary and undergraduate levels, but throughout the educational experience.

"If we could start with kindergarten," she said, "we could have students thinking about real problems in meaningful ways. We wouldn't just say, This is the math you have to do; go do it. We could say, this is a big and interesting problem, here are some tools, let's figure out how they can help you solve it. From the very beginning this approach can help students think about math in a way that's closer to how mathematicians practice in the workplace."

She said that SIAM had held several workshops on Modeling Across the Curriculum which led to a successful NSF proposal to introduce the practice of modeling in elementary schools. SIAM and CoMAP (Consortium for Mathematics and Its Applications) are also sponsoring a writing effort to produce a report called Guidelines for Assessment and Instruction in Mathematical Modeling Education based on a similar report in statistics. SIAM also organizes the Moody's Mega Math Challenge, a mathematical modeling competition for high school students, and is planning a new repository of curriculum materials in mathematical modeling.

A second emphasis by SIAM has been the development of industrial internships. "These will play a much larger role than they have in the past," she said – "connecting students to opportunities such as summer work experiences. We want to include students who come from less well-known schools, but have a solid foundation. SIAM can connect them with industrial experiences that will give them a sense of how to apply their class work in a real job setting." This effort will dovetail with PIC-math, or Preparation for Industrial Careers in Mathematics, which offers professional development for faculty who want to be involved in industrial projects and to teach math modeling for industry.

A third effort is a program supporting SIAM student chapters to bring US and international students to SIAM conferences. "We find the students are eager to share their research experiences and ideas about chapter activities."

Jim Lewis, University of Nebraska at Lincoln; Association of Public and Land Grant Universities (APLU)

Dr. Lewis said that several years ago, APLU started an initiative called the Mathematics Teacher Education (MTE) Partnership, which focuses on teacher education. The MTE Partnership seeks to recruit partners from across the nation to collaborate in the redesign of mathematics teacher preparation programs. Eligible partners include teams of at least one higher education institution and at least one K-12 school district or entity; these work together to prepare secondary mathematics teachers. "But some members of the initiative," he said, "proposed the idea that if you're going to be serious about diversifying the pool of people who teach, you have to increase the pool – not just pick your high school teachers from among those who come to your colleges and universities all ready to study mathematics."

Out of that conviction came the Active Learning Mathematics Initiative, a “place to start changing instruction.”

Active approaches to teaching math could be more helpful, he conceded, if they were used enough. “And in our research universities, we’re not preparing grad students to be ready for a role as young faculty members engaging seriously. We’re embarrassed by how many Project NeXT students are in research universities. We need to change the culture in research universities and how grad students are educated. That’s part of what APLU is working on, and we believe we have the capacity to affect how our administrative leaders – presidents, provosts – pay attention to these things. If we want significant change to undergraduate education, we’ve got to have university administrations on our side.”

Uri Treisman

Dr. Treisman, who spends much of his time working with state governments and public universities as a consultant, said he had been surprised to find how much student pathways had changed in the last decade. The University of Texas at Austin in the last semester had transferred in 88,000 courses; 62% of the baccalaureate graduates had community college credits on their transcripts. He said that the same was true for the University of Maryland, and other institutions.

He cited two related issues. One is that the economics of math departments are changing as students seek out low-tuition courses at community colleges and other access institutions; this means that the cost per course offered in R1s is “skyrocketing.” A second issue, he said, is that students are distributing their education over more institutions. Thirty years ago, the freshmen at R1s were like those at private institutions: they entered and finished at the same institution. “This is not true today. The R1s are no longer ‘islands’ in many states. They have to work with other institutions. We have to think about our joint responsibilities for student success in different ways.”

Linda Braddy, Deputy Executive Director, MAA

Dr. Braddy said that the MAA’s Committee on Early Career Mathematicians (ECM) had initiated an ECM Mentoring Network. This new project is aimed at connecting early career mathematicians with experienced mentors working in mathematics. “There are some really good programs at some institutions,” she said, “and then some institutions have nothing. The Idea is to provide mentor/mentee relationships to help people establish their own TA programs that focus on teaching. We need more R1 schools to participate to really make an impact.”

Mentors will support mentees in many ways: help explore career options, answer questions during a job search, provide advice on a first job. Most importantly, mentors make themselves available to answer questions and help make connections with the larger mathematical community.

Suzanne Doree, Augsburg College; Curriculum Renewal Across the First Two Years (CRAFTY), a subcommittee of MAA’s Committee on the Undergraduate Program in Mathematics (CUPM)

Dr. Doree said that teachers now know a great deal about what contents students need to know, and a great deal about what works in teaching different populations, “so I think we’re at a moment where we can have broad change.” She emphasized a project that had not been mentioned – the Curriculum Foundations Project, “some fabulous research done with NSF support that brought together hundreds of people and partner disciplines.” She said that CRAFTY had done two reports: “Curriculum Foundations Project: Voices of the Partner Disciplines,” and a second, similar version with recommendations for college algebra. “It’s an amazing tool to seek funding, bring together institutions, and to create models of institutional curricular change, centered on those conversations with the partners.”

On a more pessimistic note, she said, was a lack of progress in faculty development. Few institutions have moved beyond the “old model,” she said, by which people participate for the first few years of their teaching, and then for 40 years continue to teach at the same school, doing the same thing. “Today,” she said, “we need to recognize how many courses are taught to people who will be teaching elsewhere in five years. Even if they learn some good things to take to that other place, it’s a different context. So there is a need for professional development on a scale like never before.” She noted an effort by CRAFTY to collaborate with AMATYC and other organizations.

Michael Vogelius, Division of Mathematical Sciences, NSF

Dr. Vogelius briefly highlighted the NSF’s new Enriched Doctoral Training in the Mathematical Sciences (EDT). The purpose of the EDT program is to support efforts to enrich training in the mathematical sciences at the doctoral level by preparing PhD students to recognize and find solutions to mathematical challenges arising in other fields and in areas outside today’s academic setting. Graduate research training activities supported by EDT will prepare participants for a broader range of mathematical opportunities and career paths than has been traditional in U.S. mathematics doctoral training. Dr. Vogelius said he hoped the program, scheduled to run for three years, would be followed and evaluated closely with the help of “a data base of success stories.”

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APPENDIX

The following summaries were submitted by leaders of their respective mathematical societies. The purpose is to describe projects underway and provide opportunities for collaboration with other organizations.

1. Mathematical Association of America; A Common Vision for the Undergraduate Mathematics Program in 2025 (Common Vision)

The primary goal of this initiative 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. Leaders are drawn from partner organizations, including AMATYC, AMS, ASA, MAA, and SIAM.

Its premises include:

1. Mathematical scientists (mathematicians, applied mathematicians, statisticians, computer scientists, and mathematical sciences educators) can contribute to scientific initiatives 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 mathematicians, statisticians, computer 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 as key components in the preparation of scientifically literate citizens.

Mathematics and education in the mathematical sciences are in the national spotlight, in part due to the role they play in economic mobility. We intend to capitalize on this attention, and change the public perception of mathematicians and the vitality of work being done in mathematical sciences education.

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

In the seven reports below, we have identified common themes and classified them into four interdependent categories: curricula, workforce training, pedagogies, and faculty development.

* *Beyond Crossroads*, AMATYC, 2006. <http://beyondcrossroads.matyc.org/>

* *Guidelines for Assessment and Instruction in Statistics Education*, ASA, 2012.

<http://www.amstat.org/education/gaise/>

* *Guidelines for Undergraduate Programs in Statistical Science*, ASA, 2014.

<http://www.amstat.org/education/curriculumguidelines.cfm>

* *The Committee on the Undergraduate Program in Mathematics Curriculum Guide*, MAA, January 2015 (draft available online:

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*, MAA, 2012. <http://www.maa.org/sites/default/files/pdf/CUPM/crafty/introreport.pdf>

* *Modeling across the Curriculum*, SIAM, 2012. http://www.siam.org/reports/modeling_12.pdf

* *Undergraduate Programs in Applied Mathematics*, SIAM, 2014.

http://www.siam.org/reports/undergraduate_14.pdf

2. American Mathematical Society (AMS)

Activities Related to Undergraduate Mathematics Reform

Policy Committee on Education (CoE) is charged with “communication and cooperation with other organizations, providing a forum for discussion of math ed issues; provides information and makes recommendations to the society; and organizes elements of AMS meetings addressing math ed.

At JMM, the topic of the CoE panel was Active Learning Strategies for Mathematics.

Editorially managed blog On Teaching and Learning Mathematics (<http://blogs.ams.org/matheeducation>).

Partnership with CBMS publishing *CBMS Issues in Mathematics Education*, *AMS Pure and Applied Undergraduate Texts*, the *IAS/Park City Mathematics Series*, a *Student Mathematical Library*, and a new IAS/Park City series from the Secondary School Teachers Program.

Issues awards for “mathematics programs that make a difference,” including “bringing more persons from underrepresented background into some portion of the pipeline....”

3. Society for Industrial and Applied Mathematics (SIAM)

Applied and industrial mathematics education initiatives in two areas: (a) modeling across the curriculum, and (b) training for non-academic careers.

The many possible academic and non-academic careers for which a mathematics major that includes computation, data science and modeling can provide excellent preparation.

One big effort: Modeling Across the Curriculum, in collaboration with ASA and MAA, funded by NSF.

4. Mathematical Association of America (MAA); Committee on the Undergraduate Program in Mathematics (CUPM)

A long and distinguished history in the promotion and reform of the undergraduate mathematics curriculum. The story of CUPM can be referenced online at www.maa.org/cupm.

CUPM's latest report (spring 2015) concentrates primarily on the design of major programs in undergraduate mathematics, extended to include the wide range of mathematical sciences.

Does not simply provide a list of courses; specifies core cognitive and content goals, encourages departments to incorporate the goals with appropriate coursework and other experiences.

In order to sustain and cultivate interest in mathematics at the undergraduate level, CUPM tries to be sensitive to the *service* role of mathematics in many two- and four-year degree programs across college and university campuses.

Encouraged the expansion of the Calculus Project under David Bressoud, plus other group efforts.

Over a period of at least 10 years, and through its Curriculum Foundations Project, CUPM's subcommittee on Curriculum Renewal Across the First Two Years (CRAFTY) works with participants from a broad range of partner disciplines, resulting in position papers on what these disciplines want their students to learn in mathematics classes.

Articulation and placement are becoming increasingly important as students come from a vast array of backgrounds and soon will be coming from K-12 Common Core State Standards classrooms.

Printed guides of the past are being replaced by an evolving online resource. Every year or two CUPM will initiate the review and possible revision of at least one course area, program area, or other section of the Curriculum Guide.

5. Association of Public and Land-Grant Universities (APLU)

Analyzes low performance in introductory mathematics classrooms, determines promising interventions, devises plans of action, identifies measures to determine the success of its plans, and aims to help scale up the effort to many more institutions. Developed the Active Learning in Mathematics (ALM) research cluster to improve student learning and persistence in mathematics. The work is part of the APLU Mathematics Teacher Education Partnership.

Goal: Improvement of secondary mathematics teacher preparation.

Changing instructional practices in undergraduate mathematics programs appears to be notoriously difficult. Approaches include use of the Networked Improvement Community; establishment of measurable goals; understanding the attributes of the problem; defining the most likely drivers toward change; developing and implementing strategies based on those drivers; and the study and subsequent refinement of those strategies using common metrics.

A focus on pre-calculus, first-, and second-semester calculus courses includes five participating universities:

APLU believes that enduring change requires: (1) awareness of strategies for local institutional change, (2) access to ALM resources for instructors and students, (3) guidance for instructors using ALM, (4) engagement of instructional leaders, within and across institutions to encourage shared commitments, and (5) departmental and institutional incentives and resources.

6. The INGenIOuS Project

The INGenIOuS² project is a joint effort, focused on workforce development, of the MAA and the ASA, in partnership with the AMS and SIAM. The National Science Foundation provided funding.

A summary of a major workshop held in July 2013 can be seen at <http://www.maa.org/programs/faculty-and-departments/ingenious>. At the workshop, the group oversaw the formation of “communities” focused on six themes:

- Theme 1: Recruitment and retention of students
- Theme 2: Technology and MOOCs
- Theme 3: Internships
- Theme 4: Job placement
- Theme 5: Measurement and evaluation
- Theme 6: Documentation and dissemination.

The main “products” of the workshop were the following six “action threads”:

- Thread 1: Bridge gaps between business, industry, and government (BIG) and academia.
- Thread 2: Improve students’ preparation for non-academic careers.
- Thread 3: Increase public awareness of the role of mathematics and statistics in both STEM and non-STEM careers.
- Thread 4: Diversify incentives, rewards, and methods of recognition in academia.
- Thread 5: Develop alternative curricular pathways.
- Thread 6: Build and sustain professional communities.

² Investing in the Next Generation through Innovative and Outstanding Strategies.