TPSE MATH
Extracts from the Report of the Austin Meeting

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Meeting at UT Austin

Five Topics

1. Curriculum Reform
2. Removing Barriers and Opening Pathways
3. Teaching and the Economic Model of Math Depts
4. Enriching the Undergraduate Experience
5. Enhancing the Graduate Training Experience

Curriculum Reform

General finding:

The role of the mathematical sciences has broadened and deepened rapidly, with math-intensive specialties spreading through other disciplines. This provides a need and an opportunity to re-imagine the curriculum in a form that is better adapted to the requirements of students, faculty, departments, institutions, and the mathematical community. Many such efforts are happening, but they generally occur in local settings and have not been brought to scale or linked with other efforts.

General recommendation:

Mathematical science departments must re-evaluate their curricula so that they provide experiences appropriate to the skill levels and motivations of the diverse range of students, including mathematics majors, other STEM majors, and non-STEM majors. In meeting this challenge, it is critical to strengthen communication between mathematics faculty and faculty in unrelated majors, downstream departments, and two- and four-year institutions.

Curriculum Reform: List of Goals

1. Offer students a broad experience that is connected to the expanding role of the mathematical sciences and incorporates a variety of modes of mathematical thinking, such as deductive reasoning, formal manipulation, modeling and simulation, algorithmic thinking, and probabilistic and statistical reasoning. This experience should grow out of the strengths and inner coherence of the mathematical sciences, and should, when appropriate, further motivate new mathematics to be learned through the uses of the mathematical sciences.

2. Align the curriculum with the skills and understandings students need for a broad range of 21st-century careers.

3. Provide for majors a deep experience in the mathematical sciences—for example, a research experience, an open-ended project, an internship, or consulting

Curriculum Reform: List of Goals (II)

4. Work closely with partner disciplines in designing courses, possibly in the context of an institution-wide convening of stakeholders. This dialogue should also encourage experiments with partner disciplines in collaborative teaching.

5. Provide a broad palette of teaching methods – accompanied by assessment tools – to determine the effectiveness of various curriculum designs. Engage with the development of online/adaptive education and develop new curricular materials in a variety of media.

6. Create multiple pathways into and through the mathematical sciences curriculum. Offer, when possible, a mix of choices for math majors. Communicate a wide range of career options as outcomes for students.

Curriculum Reform: List of Goals (III)

7. Value, respect, and reward those who are involved in educational innovations that advance the educational goals of the department.

8. Create a community resource (or expand existing resources) for those developing educational innovations and broadening methods of teaching. Enhance communication across institutions.

9. Provide professional development opportunities to faculty, adjuncts, and graduate students to facilitate implementation of new courses and teaching methods.

10. Scale up successful programs and share data regarding program effectiveness.

Removing Barriers and Opening Pathways

Sources of barriers:

- When high school graduates are ill-prepared for post-secondary "gateway" courses, such as college algebra or calculus;
- When college students avoid mathematics because they believe they cannot understand it;
- When neither students nor faculty understand the many careers available to math and other STEM majors;
- When some part-time faculty are expected to handle the heaviest teaching loads with poor pay, no benefits, and little respect;
- When legislators blame faculty for poor student performance; and
- When partner institutions, such as community colleges and state universities, do not communicate well about their mutual needs and expectations.

Removing Barriers and Opening Pathways (II)

General finding:

Mathematics is seen by many as the #1 barrier to college completion. High school graduates are ill-prepared for post-secondary “gateway” courses; universities do not communicate well with community colleges, four-year colleges, and smaller public universities; gateway courses are poorly aligned with major academic courses.

General recommendation:

To address these findings, the mathematics community must support a major national effort to lower barriers to mathematical advancement and thinking; align post-secondary efforts with those of K-12; develop better recruitment tools to attract students to mathematics; and demonstrate to legislatures and the public the value of a stronger mathematical enterprise.

Removing Barriers and Opening Pathways (III)

Specific recommendations:

1. Develop better tools for mobilizing the mathematics community. Because the decision-making function of the math community is so fragmented and individualized, coordinated action is rare even when there is a clear consensus for action.

2. Align gateway courses with major programs of study, including the big enrolment majors and re-envisioned minors (e.g., all the sciences, nursing, journalism). Clarity from the field as a whole will help local decision making.

3. Align post-secondary courses with high school exit courses. The transition to post-secondary courses is more likely to be successful if both sides coordinate.

4. Develop better tools for recruiting students to math. This includes communicating the power and beauty of today's mathematics. For example, many engineering students choose engineering because they like math, but have little idea of the many pathways to a profession in mathematics.

Removing Barriers and Opening Pathways (IV)

5. Strengthen the roles of non-tenure faculty. There must be respect for adjunct and part-time instructors from institutions and professional associations to enhance their contributions. Also needed are appropriate honoring and reward rituals, opportunities for advancement, quality evaluations, and incentives for innovation.

6. Review the role of college algebra as the default college-level course. Multiple entry-level pathways can provide rigorous instruction for those who do not intend programs that require calculus. Focusing college algebra on those students who intend a calculus-based major can deepen the quality of instruction for those students.

7. The mathematics community should listen more closely to its various publics, which include parents, legislators, employers, and other STEM fields. The community has been ineffective in reaching out to stakeholders, building a platform for consensus, testing consensus, and acting on it in a coherent way.

Removing Barriers and Opening Pathways (V)

8. Build a community of departments across regions and types of institution. Departments gain power and perspective through networking with others. Different perspectives lead to better solutions, and each has much to learn from those who got an early start.

9. Tenure should reward the practice of education as well as the practice of research. Tenure should be associated with not only "rights" (security, pay, freedom to do research) but also "responsibilities" (mentoring, networking, communicating with stakeholders, collaborating on teaching practices).

10. Build on the capacity of departments to respond to incentives. Math departments are usually adept at meeting important targets – such as ensuring that XX% of freshmen succeed in gateway math courses and devising strategies to do so. Reward units for faculty and student success, with the support of central budgeting.

Technology, Teaching and the Economic Model

General finding:

Groups across the nation are experimenting with innovative teaching technologies; efforts to move away from a two-tiered structure of teaching; and new ways to hold down costs while increasing the quality of instruction.

General recommendation:

Departments and institutions should develop reward structures for faculty that are based less on individual action and more on collective responsibility. Because fiscal pressures are so severe, departments should work with administrations to reinvest instructional savings in departmental capacity.

Technology, Teaching and the Economic Model (II)

Technology recommendations:

1. Mathematics faculty should take the lead in bringing new teaching technologies to the classroom. If they do not take the lead, others will.
2. Departments should partner with other departments, educators, and mathematicians across the institution to incorporate current thinking on course designs, including those that use new technologies.
3. Collect data on the outcomes of using technology in teaching; rigorously evaluate the results; use the information gathered and data available from the institution for continuous improvement in classroom instruction; and carefully track costs.
4. Teach those involved in instruction the use of technologies that enable undergraduates to model phenomena and to ask and answer quantitative questions that arise across disciplines.
5. Promote, publicize, and distribute research on technology-driven innovations.

Technology, Teaching and the Economic Model (III)

Teaching recommendations:

1. Work to integrate teaching/pedagogy faculty into the life and culture of the department.
2. Affirm and honor the different tracks pursued by faculty and recognize the value that all faculty bring to the department.
3. All faculty, including tenure-track faculty and the teaching/pedagogy faculty, should engage collaboratively in undergraduate curriculum and teaching reform.
4. Encourage and enable faculty in both tracks to be aware of and incorporate the results of teaching research.
5. Collaborate with other departments at the institution, both in STEM and other disciplines that face similar concerns, to jointly develop undergraduate education reforms.
6. Explore, import, and adapt practices in other disciplines that recognize contributions to the teaching and learning mission.
7. Build collaborative networks with math faculty at neighboring institutions, especially those at community colleges, to better align curricular offerings and reform efforts at the lower division level.

Technology, Teaching and the Economic Model (IV)

Economic findings:

1. Universities and math departments are under severe economic pressures.
2. These pressures are forcing departments to find new ways to meet their responsibilities.
3. To date, the primary tactic to cut costs has been to hire part-time and adjunct faculty as teachers.
4. The fiscal pressures are unlikely to subside for many, if not most, departments.
5. University administrations are eager to find innovative means of instruction that not only hold down the growth in costs, but also improve results.

Technology, Teaching and the Economic Model (V)

Economic recommendations:

1. Develop departmental and institutional reward structures that are not based primarily on individual performance, but that recognize collective responsibility and achievement. Incentives might include FTEs, support staff, space allocation, and return of overhead from grants.

2. A structure that recognizes collective responsibility should also recognize that faculty move through different “phases” in careers when there may be more or less time for teaching, research, administrative, or inter-departmental activities. A year spent co-designing a mathematical biology course, for example, might include the expectation of a temporary slowdown in research activity. Actively pursue new teaching and learning strategies that can improve outcomes as well as lower costs.

3. Work with university administrations to develop a system whereby a substantial portion of any instructional savings are reinvested in building departmental capacity.

4. Recognize that if mathematicians do not take the initiative to enumerate *both* the costs and benefits of meeting institutional goals, some other agent or force from outside the mathematics community will define, measure, and probably minimize them.

Enriching the Undergraduate Experience

General finding:

Current undergraduate experiences offer students little understanding of the uses and relevance of mathematics; at the same time, a more quantitatively literate workforce is needed for employment in every sector.

General recommendation:

Two broad strategies are needed to drive transformation: Grass-roots efforts driven by local communities, and structural redesign mediated by a large, centralized organization, with support from professional societies and universities. Keys to both are (1) ability to scale up and evaluate innovations, and (2) efforts to build long-term relationships with stakeholder people, departments, and other institutions.

Enriching the Undergraduate Experience (II)

Findings

1. There is a national need for a more quantitatively literate workforce.
2. An increasingly diverse student body reflects the increasing diversity of the nation.
3. A variety of stakeholders depend on mathematical learning, including K-12, community colleges, government, business, and industry.
4. Mathematics has very high rates of drop / fail / withdrawal.
5. The “industrial model” of mathematics instruction prevails, continuing the long-standing lecture/recitation format. This model allows for quick scale-up to larger numbers of students, but may not be the most effective way to teach for understanding and retention.

Enriching the Undergraduate Experience (III)

6. Revenue surpluses from mathematics instruction are central to budget models in most post-secondary institutions, dissuading university administrators from moving to a less efficient but more effective model in times of constrained budgets.

7. Both budget models are more costly than MOOCs, whose role is still uncertain.

8. Few partnerships have been developed between key stakeholders, especially departments, colleges and universities, K-12 programs, and the private sector.

9. These stakeholders share levels of concern and anxiety, but little motivation to learn from one another.

10. Local innovations are seldom adopted beyond their place of origin, and their effectiveness is insufficiently assessed.

Enriching the Undergraduate Experience (IV)

Recommendations for general learning:

1. Productive persistence: Ability to work through and learn from mistakes and tolerate short-term failure; to stay engaged despite setbacks; and to stay on task while keeping sight of overall goals.

2. Deep understanding: To grasp the essential features of mathematics being studied, beyond the rote or algorithmic aspects.

3. Problem solving: Ability to bring relevant mathematics to bear on a problem, without knowing in advance what sort of mathematics is needed.

4. Communication: Capacity to convey mathematical ideas at a level appropriate to the needs and background of the audience.

Enriching the Undergraduate Experience (V)

Recommended changes in the classroom:

1. Increase instruction in use of data, statistics, modeling, and computation. Because this is in line with the Common Core Math Standards, it is particularly important in training future teachers.

2. Develop experiential learning and internship opportunities through partnerships with business, industry and government.

3. Ensure the effective use of technology in the classroom.

4. Provide ample advising and access to career services.

Enriching the Undergraduate Experience (VI)

Recommended changes in teacher support:

1. Colleague mentoring: Faculty leaders can help disseminate new teaching methods by recruiting and mentoring existing faculty. Incentives such as release time may reward the time and effort spent *outside* the classroom to acquire new skills, new language, and new colleagues.

2. Learning assistants: Teaching can be augmented by appropriately trained and supervised undergraduate learning assistants.

3. Disseminate best practices: Create or raise the profile of structures (conferences, online communities, perhaps via professional societies) to disseminate best practices among faculty and departments.

Enriching the Undergraduate Experience (VII)

Recommended means of implementation:

1. TPSE Math may serve as a coordinator and facilitator with large national organizations of universities, beginning with AAU, APLU, and AMATYC; among professional societies such as AAAS, AMS, MAA, ASA, SIAM, and JPBM; state educational agencies; federal agencies, such as NSF, PCAST, and the federal 5-tier STEM plan; and individual successful projects.
2. Adopt and disseminate rubrics and methods to help departments identify and evaluate opportunities for improvement. Create regional partnerships to foster and support transformation.
3. Create a repository for course materials and information about course and program transformation. Ensure the sustainability of the archive.
4. Promote widespread use of data, evidence, and assessment.

Graduate Training

General finding:

Despite the fact that some 60% of all mathematics PhDs will find employment outside the traditional Group I-III departments – therefore doing more teaching than research – most graduate training does not equip them for such careers.

General recommendation:

In light of the diverse careers open to math PhDs, programs should promote the development of teaching and mentoring skills; communication skills, especially with those outside the profession; and internships in the private sector. In addition, graduate candidates should be familiar with the merits of masters programs, which are often designed to meet employment needs or serve as feeder programs to PhD programs.

Graduate Training (II)

Specific findings:

1. According to recent data from the AMS, about 60% of all mathematics PhDs will eventually find employment outside the traditional Group I-III mathematics departments (that is, the kinds of department from which they graduated). This is an opportune time to adjust elements of graduate training to better prepare future graduates for this changing world.

2. For PhD recipients in mathematics who do not end up in Group I-III research departments, a significant fraction go to academic institutions that emphasize undergraduate education, or to industry or government laboratories. The group considered this to be a positive state of affairs, and an essential means of transferring vital mathematical expertise to other domains. At the same time, traditional graduate education has done little to prepare them for the wide breadth of careers now available.

Graduate Training (III)

3. While a traditional goal of graduate programs in mathematics is to develop excellent early-career mathematicians, many departments now emphasize masters programs, demand for which is significant and growing. Many such programs emphasize career advancement and professional development of relevance to many positions in government and the private sector, especially in fields of finance, bioinformatics, and cryptography. Masters content taught to middle school and high school teachers is also valuable in supporting development of mathematical content.

4. Changes underway in undergraduate programs must be accompanied by changes in graduate programs, so that current graduate students will be better equipped as teachers – especially given the reforms now being proposed. The section below contains suggestions for doing this.

Graduate Training (IV)

Recommended changes in teacher training:

1. Allow all graduate students at some (advanced) stage of their training to be in charge of their own class (i.e., not just act as a recitation instructor). This may already be happening at many larger (state) institutions, but it is equally important in smaller (private) programs. This responsibility should be accompanied by appropriate training and pedagogical instruction, so that it both responds to the needs of undergraduate students and advances the teaching skills of the graduate student.

2. Promote the development of communication skills of graduate students, especially with people outside the profession. This could be done through student-sponsored seminars as well as through special department-sponsored events with outside "coaches."

3. Strongly encourage networking activities at the graduate student level. As an essential element of early career development, networking options could be developed, for example, by an appropriate expansion of project NeXT and by increased use of the Mathematics Research Communities program.

Graduate Training (V)

Recommended changes in curricula:

1. Increase exposure to computational work that is relevant to their area of research and, more generally, to a potential job or career. Such exposure could be facilitated by a wide-ranging course or seminar that would introduce such desirable skills as computation, statistics, and basic ideas of continuous and discrete modeling.

2. Increase emphasis on mentoring by graduate students of other graduate students and undergraduates, much in the spirit of a Research Training Grant.

3. Increase access to internships to familiarize graduate students with a range of employment opportunities, especially in the private sector. Because not all departments have the resources to do this, a national database of internship offerings should be created, possibly by one or more of the national societies or NSF-sponsored national institutes.

Graduate Training (VI)

Recommended guidelines for masters programs:

1. In the interest of diversifying pathways to mathematically intensive careers and better build a mathematically educated workforce, continue to design and implement more mathematics masters programs. In particular, this degree may help address the need for better-trained teachers at secondary and post-secondary levels.

2. Implement more masters programs that serve as feeders to PhD programs for undergraduates with weaker backgrounds without lowering the level of those PhD programs.

Cross-cutting Theme: Diversity

Diversity outreach efforts:

Participants at the Austin meeting heard about and discussed efforts to increase the number of undergraduate and graduate students from traditionally underrepresented groups, including female, African-American, and Latino students. While there was strong support for these individual efforts, there was also a feeling that such efforts should be sustained by national societies or other large organizations if they are to develop long-term effectiveness. Critical mass is important, and both alumni and current graduate students can be tapped as part of an effective recruiting effort .

Several attendees broadened the conversation to call for the participation of more faculty and students from smaller institutions, including HBCUs, where education and training are often of higher priority than research. Accordingly, TPSE Math has planned to broaden its own reach, both in planned regional meetings and in its own leadership.

Whither TPSE Math?

The TPSE Math group that organized the Austin meeting has discussed a continuation of its activities in terms of an “enabling body.” In other words, it anticipates activities that include a combination of outreach, networking, information-gathering, publicity, and support for mathematicians already developing and evaluating new models and techniques of education.

It also sees value in the role of brokering partnerships across the often-fragmented mathematics community – causing good things to happen by suggesting appropriate partnerships. The group hopes to build on innovative ideas already being implemented at local and national levels, rather than formulating new ideas that are likely to be duplicative. TPSE Math believes that a well-played brokering role can promote positive culture change by cross-fertilizing “around the edges” and promoting a collective sense of where things need to move. It hopes to collaborate with the mathematics community and help it identify innovations likely to be successful and scalable for use nationwide.