The TPSE Math Priorities

• Lower-Division Pathways
• Upper-Division Pathways
• Graduate Education
• Teaching Strategies and Practices
Lower-Division Pathways

A Status Report
on Lower Division Pathway Reform
The Traditional Remedial Pathway

Student Progression Through the Developmental Math Sequence

- 100% (63,650) Referred to 3+ Levels of Remediation
- 26% Did Not Enroll in Next Course
- 15% Level 3+ Course
- 7% Level 2 Course
- 4% Level 1 Course
- 4% Gatekeeper
- 2% Passed Gatekeeper Math
- 11% Did Not Pass/Complete Course
### The Problem

<table>
<thead>
<tr>
<th></th>
<th>4 Year Institutions</th>
<th>2 Year Institutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>College Algebra and below</td>
<td>58%</td>
<td>56%</td>
</tr>
<tr>
<td>Calculus</td>
<td>35%</td>
<td>37%</td>
</tr>
<tr>
<td>Advanced Courses</td>
<td>6%</td>
<td>7%</td>
</tr>
<tr>
<td>Other Courses (2 Year)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL Enrollment (in thousands)</td>
<td>1614</td>
<td>1607</td>
</tr>
</tbody>
</table>
An Extraordinary Resource

- National Academy of Sciences, Engineering and Medicine
- Workshop on Developmental Education Reform
- Chaired by Howard Gobstein, APLU
- See: http://sites.nationalacademies.org/DBASSE/BOSE/Developmental_Math/index.htm
Targets of Reform circa 2007
The Multiple Math Pathways Model

Developmental mathematics students should have access to:

1. Multiple pathways aligned to specific fields of study
2. Acceleration that allows students to complete a college-level math course in one year
3. Intentional use of strategies to help students develop skills as learners directly linked to their courses
4. Curriculum design and pedagogy based on proven practice coupled with a context sensitive improvement strategy
Statistics Pathway is designed for students seeking a college-level statistics course as part of their general education requirement for majors in fields including:
- Nursing
- Social Work
- Criminal Justice

Quantitative Reasoning Pathway is designed for students pursuing a field of study in which general education math is a requirement. These fields include majors in:
- Communications
- Graphic Design
- Paralegal

STEM-Prep Pathway is designed for students seeking a STEM or mathematics-intensive major in fields including:
- Petroleum Engineering
- Computer Science
- Chemistry
MORE THAN TRIPLE THE SUCCESS IN HALF THE TIME

(2017-18)
<table>
<thead>
<tr>
<th>For students enrolling in developmental education courses:</th>
<th>All FTIC, Community College Students</th>
<th>Dana Center Mathematics Pathways</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developmental Education Completion</td>
<td>29% in one year n=31,962</td>
<td>60% in one semester n=6,120</td>
</tr>
<tr>
<td>Gateway Course Completion: Corequisite model</td>
<td>13% in one year n=31,962</td>
<td>72% in one semester n=1,159</td>
</tr>
</tbody>
</table>

Math Success in Indiana

In the past, for every 100 students attempting Math remediation...

100
Attempted remedial math

49
Completed remedial math

36
Attempted gateway math

29
Completed gateway math

Leave Pipeline: 51

2009 ATD cohort

Time lapse: 1 to 3 years

In Fall 2014 co-req. model expansion, for every 100 students attempting Math remediation...

100
Attempted remedial & gateway math

64
Completed gateway math

36
Completed remediation

Time lapse: 1 semester

Fall 2014: 691 students enrolled in MATH 080/123.
Spring 2015: 2,019 students enrolled in MATH 080/123.

Source: Ivy Tech Community College (2015)
Logue, Watanabe-Rose, & Douglas Randomized Controlled Trial (conducted Fall 2013) – Course Pass Rates

- **EA (Traditional Remediation)**: n=2, 39.3%
- **EA-WS (Traditional Remediation + Workshop)**: n=2, 44.9%
- **Stat-WS (College-Level Course + Workshop)**: n=2, 55.7%
Logue, Watanabe-Rose, & Douglas Randomized Controlled Trial (conducted Fall 2013)

CUNY RCT: Enrollment Status After 3 Years

<table>
<thead>
<tr>
<th>Course</th>
<th>Not Enrolled</th>
<th>Enrolled</th>
<th>Graduated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elem Alg</td>
<td>17.1%</td>
<td>30.0%</td>
<td>52.9%</td>
</tr>
<tr>
<td>Elem Alg w/ WS</td>
<td>19.4%</td>
<td>25.0%</td>
<td>55.6%</td>
</tr>
<tr>
<td>Stat w/ WS</td>
<td>25.2%</td>
<td>26.7%</td>
<td>48.1%</td>
</tr>
</tbody>
</table>

N=297 for Elem Alg, N=313 for Elem Alg w/ WS, N=297 for Stat w/ WS
### Completion of Gateway Math by ACT Sub-score

**Community College Pre-requisite Model vs. Co-requisite Model**

<table>
<thead>
<tr>
<th></th>
<th>Pre-requisite Model AY 2012-13</th>
<th>Full Implementation</th>
<th>No ACT</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>2.7%</td>
<td>27.1%</td>
<td>0%</td>
<td>13%</td>
</tr>
<tr>
<td>14</td>
<td>3.8%</td>
<td>33.4%</td>
<td>0%</td>
<td>14%</td>
</tr>
<tr>
<td>15</td>
<td>6.8%</td>
<td>42.6%</td>
<td>0%</td>
<td>15%</td>
</tr>
<tr>
<td>16</td>
<td>11.5%</td>
<td>51.1%</td>
<td>0%</td>
<td>16%</td>
</tr>
<tr>
<td>17</td>
<td>19.7%</td>
<td>61.1%</td>
<td>13.1%</td>
<td>17%</td>
</tr>
<tr>
<td>18</td>
<td>25.6%</td>
<td>65.9%</td>
<td>13.1%</td>
<td>18%</td>
</tr>
<tr>
<td>No ACT</td>
<td>12.3%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>11.5%</td>
<td></td>
<td></td>
<td>65.9%</td>
</tr>
</tbody>
</table>

**Results of TBR Co-requisite Full Implementation**

- AY 2012-13: 2.7%
- Full Implementation: 27.1%
- No ACT: 13.1%
- Total: 51.7%
States Implementing Co-Reqs at Scale
The Multiple Pathways Model
At the campus level, pathway reform must be:

*student centered,*

*Faculty and staff-driven,*

*administrator-supported,*

*policy-enabled,* and

*culturally reinforced.*
Pathways Reform at the System Level

<table>
<thead>
<tr>
<th>Level</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>NATIONAL</td>
<td>Legitimize math pathways through professional associations</td>
</tr>
<tr>
<td>STATE/SYSTEM</td>
<td>Coordinate policy, institutional and organizational efforts across the system</td>
</tr>
<tr>
<td>REGIONAL</td>
<td>Support regional stakeholders regarding transfer &amp; applicability policies</td>
</tr>
<tr>
<td>INSTITUTIONAL</td>
<td>Build tools &amp; services that help colleges implement systematic reform</td>
</tr>
<tr>
<td>FACULTY &amp; CLASSROOM</td>
<td>Develop professional learning &amp; curricular resources informed by faculty</td>
</tr>
</tbody>
</table>

The Dana Center works at multiple levels of the system to support institutions in operationalizing the DCMP model.
Pathway Reform: Math Faculty Mobilization

“...charged with determining how the System’s colleges could dramatically improve success rates in gateway mathematics courses without compromising the disciplinary integrity of these courses.”

—From University System of Georgia: Transforming College Mathematics
Recommendations from the University System of Georgia Mathematics Task Force

1. Focus on supporting success in college credit-bearing, gateway mathematics courses for all students.
2. Aligning gateway mathematics course sequences with academic programs of study. In particular, College Algebra should not be the default class for non-STEM majors.
3. Implement a co-requisite approach to support student success in gateway mathematics courses.
4. Develop year-long mathematics pathways for students with significant gaps in preparation.
5. Use multiple measures to place students in gateway courses and appropriate supports.
6. Terminate use of COMPASS as an exit examination.
7. Align the outcomes of gateway mathematics courses with the Common Core Georgia Performance Standards (CCGPS) for Mathematics.
8. Develop advising systems and protocols for placing students in gateway mathematics courses and co-requisite supports that align with their intended programs of study.
Essential Partnerships

• CBMS organizations
• Higher education organizations, e.g., APLU, AASCU, AACC, NASH
• Philanthropy: e.g., the Strong Start coalition (i.e., BMGF, Kresge, Ascendium)
• Policy and governance organizations, e.g., Education Commission of the States, State Higher Education Executive Officers, Achieve
Next Steps: From Scaling Pilots to Innovation at Scale

Scale: spread, depth, ownership, and changes in normative practice and policy

1. Support implementation in new systems
2. Support continuous improvement in existing sites
3. Focus RUME and other research communities on studying implementation, especially about students who do not benefit from these strategies
More Next Steps

4. Keeping the reform vibrant
5. Keeping the reform aligned with parallel reforms
6. Keeping the reforms resonant with drivers of system change
A final comment on equity...
Upper-Division Pathways

Enhancing upper-division curricula in response to evolving career opportunities, developments in mathematical research, and demand from other departments for mathematics courses.
From a recent (successful) TPSE grant proposal

- Objective 1: Establish regional communities working in collaboration on two TPSE priorities: Upper-Division Pathways and Graduate Education.
- Objective 5: Build the culture of innovation in math departments by strengthening the capacity of math department chairs and others in a position to effect change in their departments and institutions; cultivate new leaders.
TPSE Math will convene regional workshops on upper-division pathways. Each convening will bring together math department chairs and faculty, alumni, university administrators, and employers.

After experimenting with different formats, TPSE has found that workshops are most effective when they include facilitated breakout groups focusing on salient issues; when key discussion questions are identified and communicated in advance; and when participants from similar kinds of institutions are given ample opportunity to work together in small groups.
TPSE’s intent is to help faculty be ready to play appropriate and timely roles as opportunities arise.

As an adjunct to each regional convening, TPSE will provide small seed grants, awarded on a competitive basis, to regional communities of faculty interested in pursuing followup projects.
The seed grants mentioned above to plan, adapt, and carry out activities based on what participants have learned and initiated at the workshops. The underlying strategy is that such grants will energize the community and catalyze further work.

TPSE will steward the formation of regional working communities allied around institutional type, geographical location and departmental priorities, and perhaps also including employers of math-educated graduates.
Traditionally, institutional initiatives for new courses or pathways have come from people outside the math department, who have had to struggle to gain the interest of mathematicians. TPSE will encourage habits of anticipation and utilization of opportunities to learn about interesting new models for teaching, learning, and curriculum design. The goal is not merely to prepare chairs for expected difficulties, but to guide them toward being proactive, anticipating when, for example, they should step forward to advocate a program in data science, modeling, or other subjects.
TPSE will hold two summer leadership institutes specifically to prepare present and future chairs for service as change agents at their institutions. For each institute, TPSE will recruit 20 to 25 current and incoming chairs and/or midcareer faculty. These sessions will focus on competitive proposal writing, budget management, administrative systems, and other complex tasks facing any chair. They will be designed to make it easier for chairs and department leaders to respond to current and likely future issues, and to learn from others.
Upper-Division Pathways
Regional Meetings

2018

• New England Regional Meeting on Upper-Division Pathways, WPI - June 11-12
• Mountain Regional Meeting on Upper-Division Pathways, Utah Valley U - Sept 28-29
Upper-Division Pathways
Regional Meetings

2019
• Southeast Regional Meeting on Upper-Division Pathways, Morehouse College - June 10-11

2020 (dates/locations tbd)
• Midwest Regional Meeting on Upper-Division Pathways
• Southwest Regional Meeting on Upper-Division Pathways
Example: Mountain Regional Meeting on Upper-Division Pathways

• Local organizers Michael Dorff (BYU) and Bob Palais (Utah Valley U)
• About 60 participants
• Local organizers of next regional meeting attend, so at this one Curtis Clark and Benedict Nmah (Morehouse College) attended.
Industry Panel Michael Dorff, BYU – Moderator

- Charles Cox, BioFire Diagnostics
- Stephanie Fitchett, Transamerica
- Marylesa Howard, Nevada National Security Site
- Uwe Mayer, eBay
- Eric Ringger, Zillow
Industry/Academia Breakout
Theme 1: Academia/Industry Interface
Theme 2: UDP Mathematics Content and Structures for Industry
Theme 3: Preparing Students for Careers in Industry

Reflections from Funding Organizations
• Elise Henson, Carnegie Corporation of New York
• Lee Zia, NSF (EHR/DUE)
# Outcome: sketch of minor in data science

<table>
<thead>
<tr>
<th>Course</th>
<th>Key topics to cover</th>
<th>Prerequisites</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Intro to Programming</td>
<td>Python, fundamentals of coding</td>
<td>None</td>
</tr>
<tr>
<td>B Linear Algebra</td>
<td>Matrix fundamentals, Least squares, Eigenvalues &amp; Eigenvectors</td>
<td>Mathematical Maturity</td>
</tr>
<tr>
<td>C Statistics</td>
<td>Regression, Hypothesis testing, Basic probability</td>
<td>Mathematical Maturity</td>
</tr>
<tr>
<td>D Working with Data</td>
<td>SQL, Data wrangling (acquisition, selection, cleaning, missing data, evaluation), Ethics, Visualization. Project</td>
<td>A</td>
</tr>
<tr>
<td>E Machine Learning</td>
<td>Optimization, supervised (train/test/validate, overfitting, unbalanced data, logistic regression, SVM, random forests), unsupervised (k-means, dimension reduction) Project</td>
<td>A, B, C, D</td>
</tr>
</tbody>
</table>
Leadership team formed:

- Vinodh Chellamuthu (Dixie State University, St George UT)
- Vera Furst (Fort Lewis College, Durango CO)
- Jingsai Liang (Westminster College, Salt Lake City UT)
- Matt Welz (Fort Lewis College, Durango CO)

Working with TPSE and Michael Dorff to increase awareness of data-science related opportunities among the Mountain Regional Network members.
First webinar took place on March 6:

Nick Horton on “Data Science for Undergraduates: Opportunities and Options”
## Trends

<table>
<thead>
<tr>
<th>Field</th>
<th>Master’s 2000</th>
<th>2015</th>
<th>% change</th>
<th>PhD 2000</th>
<th>2015</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math &amp; Stats</td>
<td>3,295</td>
<td>8,269</td>
<td>151</td>
<td>777</td>
<td>1,951</td>
<td>151.1</td>
</tr>
<tr>
<td>All S &amp; E</td>
<td>96,230</td>
<td>180,955</td>
<td>88</td>
<td>27,862</td>
<td>44,521</td>
<td>59.8</td>
</tr>
</tbody>
</table>

*Graduate STEM Education for the 21st Century* (The National Academies Press, 2018)

PDF available at nap.edu/25038
“The committee envisions a 21st-century U.S. graduate science, technology, engineering, and mathematics (STEM) education system that builds on the substantial strengths of the current system but better meets the evolving needs of its students, the scientific enterprise, and the nation.”
3 recommendations

Students would

• encounter a variety of points of view about the nature, scope, and substance of the scientific enterprise and about the relationships among science, engineering, and society,

• have opportunities to communicate the results of their work and to understand the broader impacts of their research,

• be encouraged and given time, resources, and space to explore diverse career options, perhaps through courses, seminars, internships, and other kinds of real-life experiences.
Challenge: We must enhance and adjust graduate education to prepare students better for all types of careers in an evolving world.
"The United States is the preeminent global hub for academic training."

(Senior Policy Analyst Neil G. Ruiz of the Brookings Institution in *The Geography of Foreign Students in U.S. Higher Education*)
The Context

MATH PHD EMPLOYMENT BY SECTOR

- Academic/Institute
- Business & Industry
- Government

The Context

Math PhD vs US Unemployment

Math PhD unemployment vs US Unemployment
The Context
The Context
The Context
### Graduate training vs Skills required

<table>
<thead>
<tr>
<th>Cornell PhD requirements:</th>
<th>Skills in the workplace:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• First year courses</td>
<td>• Critical thinking</td>
</tr>
<tr>
<td>• (No written quals)</td>
<td>• Teaching</td>
</tr>
<tr>
<td>• Admission to candidacy</td>
<td>• Communication</td>
</tr>
<tr>
<td>• Language requirement</td>
<td>• Programming</td>
</tr>
<tr>
<td>• Thesis + Defense</td>
<td>• Working in teams</td>
</tr>
<tr>
<td>• (Masters in minor field)</td>
<td>• Leadership</td>
</tr>
<tr>
<td></td>
<td>• Mentoring</td>
</tr>
<tr>
<td></td>
<td>• Confidence</td>
</tr>
</tbody>
</table>
Beyond academia: the skills

— **Mathematics:** graph theory, algebraic codes, applied category theory, natural language processing, data analysis, modeling, machine learning; algorithms, analysis, discrete math, dynamics, linear algebra, PDE, scientific computing, probability, statistics

— **Skills:** critical thinking, working on imprecise problems, pattern finding, programming, proofs, working with interdisciplinary teams, communication, management

— Application areas: ... save the world
The careers

- Statistician
- Accountant
- Actuary
- Professor
- Trader
- Meteorologist
- Software Engineer
- Data Scientist
- Financial Engineer
- Computational Mathematician
- Cryptographer
- Economist
- Network Engineer
- Quantitative Researcher
- Mathematician
- Quantitative Analyst
- Computer Engineer
- Software Modeler
- Cybersecurity Specialist
- Biostatistician
- Machine Learning Professor
The Questions

• Does our graduate training prepare students for academic careers?
• Does our graduate training prepare students for careers beyond academia?
• What models are there for enhanced graduate training?
• What can TPSE do to support enhanced graduate training?
Aspirational goals

Students will
• encounter a variety of points of view about the nature, scope, and substance of the scientific enterprise and about the relationships among science, engineering, and society;
• have opportunities to communicate the results of their work and to understand the broader impacts of their research;
• be encouraged and given time, resources, and space to explore diverse career options, perhaps through courses, seminars, internships, and other kinds of real-work experiences.
Aspirational goals

• Can we imagine new graduate programs specifically aiming to prepare students for nonacademic careers?

• How can we enhance current programs to better prepare mathematicians to advise mathematics students who face a very broad spectrum of ever changing mathematical careers?
Please join us for a West Regional Meeting!

**Focus:** Graduate Education

**Location:** University of Southern California

**Date:** September 2019 (tba)
Vision statement

– “...enable every student to develop the mathematical knowledge and skills necessary for productive engagement in society and the workplace

Objective:

– Study the use of innovative teaching practices, including uses of technologies
– Advocate for widespread adoption of those that demonstrate improved learning outcomes

Primary partner to Date:

– ITHAKA
Modest activities so far:

– TPSE meeting at UM March, 2017
  • 13 sessions of invited presentations; 8 on teaching strategies

– ITHAKA/TPSE Gates Foundation funded project on adaptive learning
  • ITHAKA to discuss
  • Can adaptive learning platforms improve student outcomes?
Common Vision:

– Partnership among AMATYC, AMS, ASA, MAA and SIAM
– Report authored by Karen Saxe and Linda Braddy
– “The status quo is unacceptable”
– Five major initiatives:
  • Update the curriculum
  • Articulate clear learning pathways
  • Scale-up evidenced based pedagogical methods
  • Address challenges at student transition points
  • Establish stronger connections with other disciplines
The challenges to innovation include:

– Many math departments under duress from growing enrollments and declining resources

– Limited resources make it difficult to develop and launch new courses and teaching strategies

– Heavy reliance on part-time, iterant teachers, especially at lower division level complicate introduction of innovative strategies, faculty development
For this afternoon session:

– How can TPSE partner with the associations and others to improve the quality and impact of undergraduate mathematics instruction?

From Common Vision:

– Develop a series of workshops for chairs on innovations in teaching and learning strategies, curricular change

– Support development and scale-up of evidenced based successful curriculum and instructional innovations

– Collaborate on the creation of a well publicized clearinghouse of successful pedagogical innovations