APLU Science and Mathematics Teacher Imperative

MATHEMATICS TEACHER EDUCATION PARTNERSHIP

Increasing Student Engagement in Introductory Mathematics Courses: The Mathematics Teacher Education Partnership

Conference Board for the Mathematical Sciences

Forum 2014

Presenters

- Howard Gobstein, Association of Public and Land-grant Universities
- W. Gary Martin, Auburn University
- W. James Lewis, University of Nebraska--Lincoln
- Robert Tubbs, University of Colorado Boulder

Session Outline

- Overview of MTE-Partnership
- The “problem”
- Table discussion #1
- Reports from partners:
  - University of Nebraska-Lincoln
  - University of Colorado Boulder
  - Auburn University
- Table discussion #2
- Questions and answers

MTE-Partnership

Organized by the Association of Public and Land-grant Universities (APLU)

- *"a research, policy, and advocacy organization representing 230 public research universities, land-grant institutions, state university systems, and related organizations."*

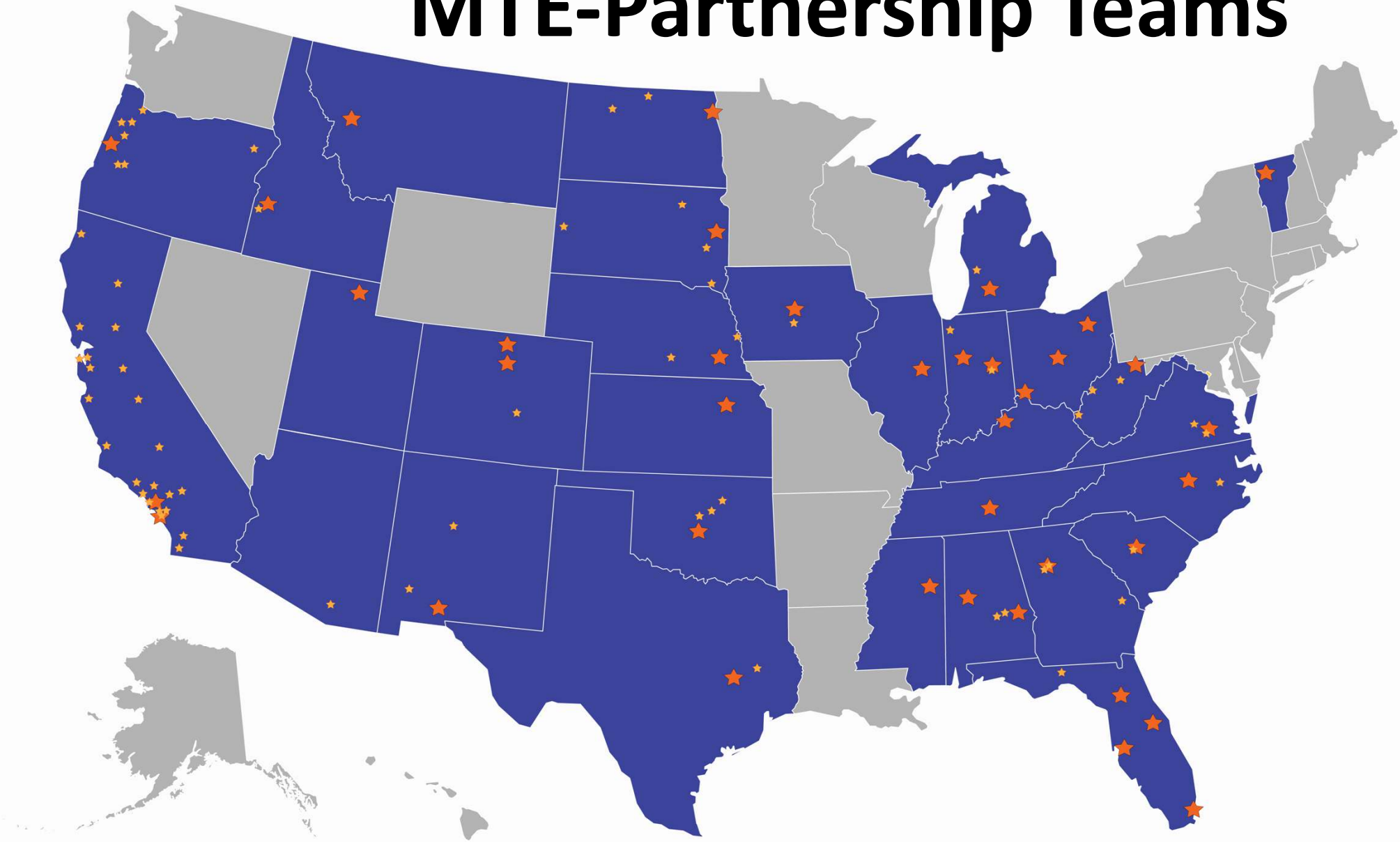
as a part of its Science and Mathematics Teacher Imperative (SMTI):

- *an "ambitious effort to help public higher education institutions assess and improve the quality, and increase the number and diversity of K-12 science and mathematics teachers."*

MTE-Partnership Membership

- Consists of 38 partnership teams led by APLU/SMTI institutions
- Teams must demonstrate continuing involvement of:
  - Mathematics educators
  - Mathematicians
  - K-12 educators

MTE-Partnership Teams



38 Partnership Teams – 30 States:

- **89 universities and 9 community colleges**
- **Over 100 school systems**

MTE-Partnership Goal

To transform the preparation of secondary mathematics teachers to ensure they can promote mathematical excellence in their future students, leading to college and career readiness as described in the Common Core State Standards for Mathematics (CCSS-M) and other standards.

"To set the bar for the nation in secondary mathematics teacher preparation"

Improvement Target

Creating a "gold standard"
Programs document that their graduates are capable of providing the ambitious instruction and deep learning compelled by CCSSM, based on benchmarks to be developed by the MTE-Partnership

More and better new teachers
To prepare *<target number>* of graduating secondary mathematics teachers with an emphasis on increasing diversity.

Primary Drivers

Creating a Vision
Creating a common vision of and commitment to SMTP among stakeholders

Clinical Preparation
Developing and supporting mentor teachers who can provide field experiences that support candidates' development of instructional practices.

Content Knowledge
Developing candidates' knowledge of mathematics needed to support student learning of content and practices

Recruitment and Retention
Attract and maintain an adequate supply of candidates

Efforts in Progress

- **Developing Effective Clinical Experiences** *Mentor professional development; alternative models*
- **Actively Learning Mathematics** *Improving instruction in introductory mathematics classes*
- **Building Communities and Courses** *Addressing specific mathematical needs of secondary teachers (cf. METII)*
- **Knowledge-for-Teaching-Mathematics Tasks (KTMT)** *Assessing mathematical knowledge for teaching*
- **MATH: Marketing for Attracting Teacher Hopefuls** *Moving beyond advertising to attract candidates*

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Association of Public and Land-grant Universities SMTI Science & Mathematics Teacher Imperative

First Things First

- Currently, in colleges and universities across the U.S. too many students who might pursue a STEM career are not succeeding in freshman mathematics courses. This can be a barrier to all STEM careers – including secondary mathematics teaching.
  - High DFW rates
  - Low rates of persistence
  - Limited exposure to mathematical habits of mind
- The Active Learning Mathematics Research Action Cluster seeks to change this situation by actively engaging students in learning precalculus and calculus.

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Engage to Excel
(Presidents' Council of Advisors on Science and Technology [PCAST], 2012)

- Fewer than 40% of students who enter college intending to major in a STEM field complete a STEM degree.
- High-performing students frequently cite uninspiring introductory courses as a factor in their choice to switch majors.
- Low-performing students with a high interest and aptitude in STEM careers often have difficulty with the math required in introductory STEM courses.
- Many students, particularly members of groups underrepresented in STEM fields, cite an unwelcoming atmosphere.

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SMTI
Science & Mathematics Teacher Imperative

Cautionary Note from the PCAST Report

Promising strategy to be explored:

- "college mathematics teaching and curricula developed and taught by faculty from mathematicsintensive disciplines other than mathematics, including physics, engineering, and computer science"

That is…

- if mathematics departments don't own the problem, someone else will!

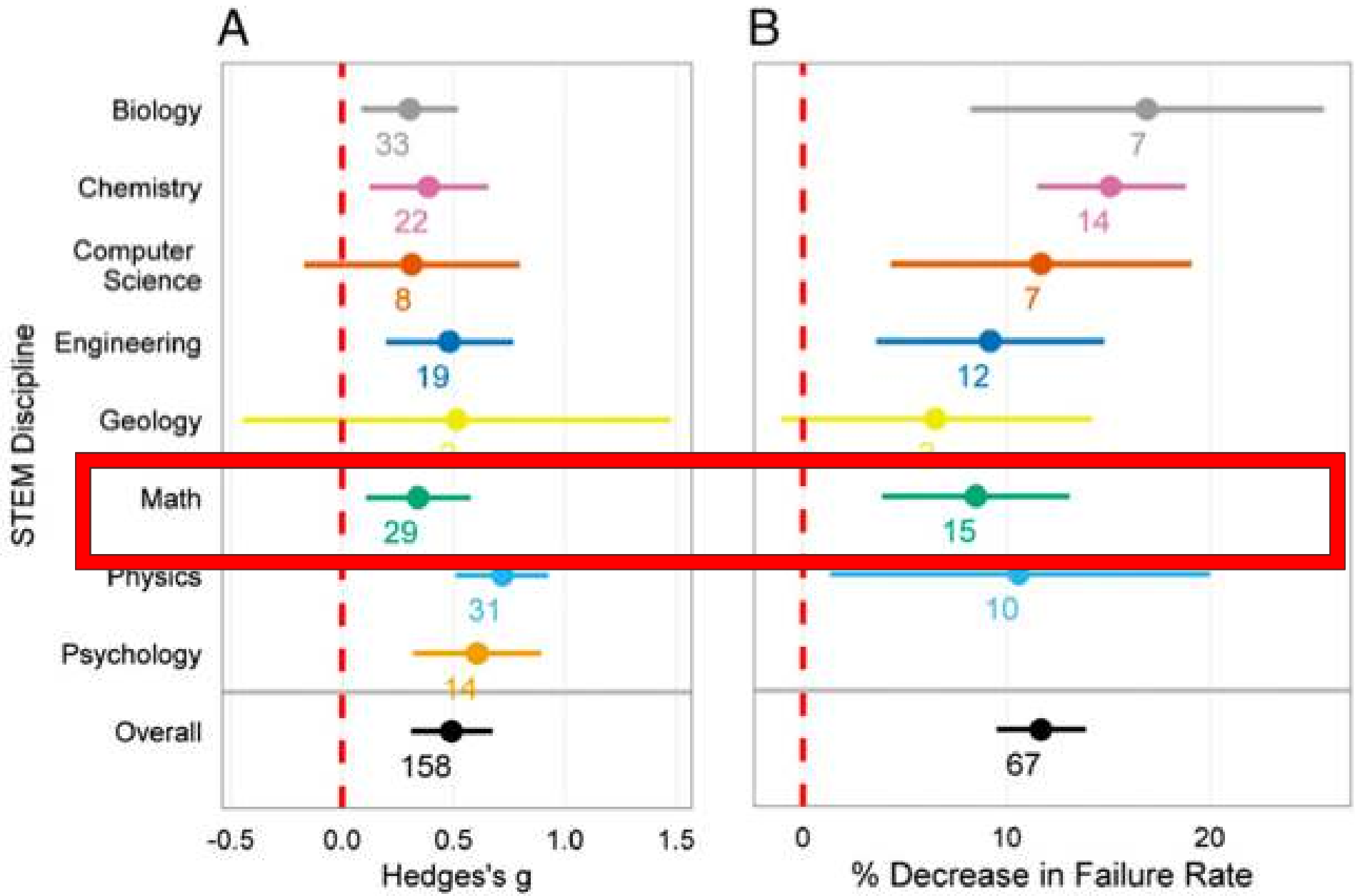
Potential of Active Learning Strategies

- PCAST: “Classroom approaches that engage students in “active learning” improve retention of information and critical thinking skills, compared with a sole reliance on lecturing, and increase persistence of students in STEM majors.”
- Transforming Post-Secondary Education in Mathematics (TPSE Math) aims to effect constructive change in mathematics education at community colleges, 4-year colleges and research universities.

Impact of Active Learning

- Freeman et al. (2014). “Active learning increases student performance in science, engineering, and mathematics.” *Proceedings of the National Academy of Sciences*.
- Meta-analysis of 225 studies that reported data comparing student performance in STEM courses under traditional lecturing versus active learning.

Impact of Active Learning



Outcomes of Active Learning (Freeman et. al, 2014)

- Increases in examination performance would raise average grades by a half a letter.
- Failure rates under traditional lecturing are 55% higher than the rates observed under active learning.

Table Discussions

- Is student success in freshman mathematics an important issue on your campus? Your department?
- Does your department currently have a focus on freshman mathematics?

Active Learning Mathematics RAC

- Five university teams:
  - Auburn University (Ulrich Albrecht)
  - University of Colorado-Boulder (David Webb)
  - University of Nebraska at Omaha (Angie Hodge)
  - University of Nebraska-Lincoln (Jim Lewis)
  - West Virginia University (Vicki Sealey)
- Funding from Helmsley Trust supports the work of this group

General Approach

- Increase students' active engagement in learning mathematics via:
  - emphasis on concepts, problem solving, and motivating examples;
  - group work in class;
  - group assignments outside of class;
  - use technology to increase practice outside class;
  - development of habits of mind (a.k.a. "Standards for Mathematical Practice");
  - development of communication skills;
  - develop a supportive classroom culture where students believe they belong and can succeed.
- Important to increase the supply of mathematics teacher candidates and candidates for other fields.

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Lessons Learned (Thus Far)

- Active learning strategies *appear* to have a meaningful impact on student success.
- Despite a significant range in local contexts commonalities exist that present important opportunities for mutual learning.
- Good teaching (as defined by Bressoud et. al) is more important than reform teaching.
- Collecting data from students is challenging.

Active Learning Mathematics

Nebraska's Story

Jim Lewis
University of Nebraska-Lincoln

University of Nebraska Lincoln

Campus Priorities

- **Grow to 30,000 students** (currently 25,000)
- **Increase 6-year graduation rate** to 70% (or higher)
  - 67% in 2014 (Fall 2008 class)
  - 84% First year retention rate in 2013-2014
- $300 million in annual research expenditures
- Significant increase in number and recognition of faculty

The Centrality of Mathematics

Fall 2014 – the Department of Mathematics taught:

- 13.3% of all courses taught at UNL
- 67.4% of all first-time freshmen
- Five math classes are among the "top 15" with respect to serving first-time freshmen.
  - No other department teaches more than 40% of first-time freshmen.

Mathematics is the largest producer of student credit hours on campus. If UNL is to increase its 6-year graduation rate, it must start by increasing student success in freshmen mathematics classes.

Transforming Instruction to Increase Student Success

Judy Walker became department chair in 2012 and launched an initiative to improve student success in precalculus mathematics courses.

Our hypothesis was that by changing to an instructional format that emphasizes active learning and student responsibility for their own learning, we can improve student success as measured by i) mathematics learned, ii) grades received and courses passed, iii) attitudes towards mathematics, and iv) success in subsequent mathematics classes.

Target Courses

Math 101 – College Algebra (3 credits)

Math 103 – College Algebra & Trig (5 credits)

Together these courses serve about 1000 students including 770 first-time freshmen (approximately 16.5% of FTF).

Courses are primarily taught by graduate students who are often teaching their own class for the first or second time. Prior to Fall 2012, lecture was the dominant instructional approach and GTAs were supervised by a long-term master's level lecturer.

Historical Success Rates

Fall Success Rates

	2007	2008	2009	2010	2011	Ave
Math 101	63%	61%	60%	68%	60%	**62.4%**
Math 103	66%	65%	68%	65%	70%	**66.8%**

Spring Success Rates

	2008	2009	2010	2011	2012	Ave
Math 101	65%	65%	64%	51%	58%	**62.4%**
Math 103	59%	61%	55%	51%	63%	**57.8%**

- . . . and substantial variation from section to section.

(Success rate = % of students who earn a C or better)

Getting Started

- In Spring/Summer 2012 we brought in Karen Rhea and then Gavin LaRose from the University of Michigan to advise us on a redesign of our instructional approach using “Michigan calculus” as our model.
- We invested modestly in the development of lesson plans, hiring two graduate students to write lesson plans in the summer of 2012.
- Responsibility for supervision continued to be the responsibility of a lecturer.

Fall 2012 – Our first effort at reform

- Common course policies and lesson plans, with a focus on active learning and conceptual understanding
- Conducted research project on instructor/student attitudes
- Created First-Year Mathematics Task Force to ensure faculty oversight
- Changes came too late to change the textbook
  - Text poor match to our approach
- Insufficient training for GTAs
- GTAs were overwhelmed

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Success rate in Math 101 went down: **59%**

2013 – A new start

- Spring – I volunteered to be the convener for Math 101. Changes included:
  - Weekly meetings with GTAs
  - Increased involvement of faculty on the first year task force
  - Focused on writing good exams, grading, and providing GTAs with instructional advice

Success rate in Math 101 increased to: **73%**

AY 2013-2014

- College Algebra is the preferred “first course” for GTAs after year as a calculus recitation instructor
- Chose new textbook aligned with an active instructional approach and emphasis on applications of mathematics
- Intensive professional development workshop for GTAs teaching precalculus mathematics courses
- Significant revision of curriculum materials

  (Student Guide, Instructor Guide, new lesson plans)
- Use of WeBWorK for homework
- Prerequisite Mastery Exam
- Team Quizzes
- Funding from APLU/Helmsley Trust to support research

Some good news

- Student success increased in Fall 2013 but dropped somewhat in Spring 2014

	Fall 2007-2011 Ave	Fall 2012	Fall 2013
Math 101	62.4%	59%	**80%**
Math 103	66.8%	72%	**77%**

Spring	Spr 2008-2012 Ave	Spr 2013	Spr 2014
Math 101	62.4%	**73%**	70%
Math 103	57.8%	74%	**54%**

Fall 2014 – Total Commitment to Active Learning

- Hired Director of First-Year Mathematics
- Renovation of a building for active learning classrooms
  - Four classrooms dedicated to precalculus mathematics classes
- Renovation of Math Resource Center
  - Larger and more inviting facility
- All GTAs teaching their own course for the first time get a one-course teaching reduction to have time to take a 3-credit pedagogy course to develop teaching ability
- Extended class time in Math 101 and 103
- Learning Assistants in (almost) all sections of 101 & 103
  - Funding from APLU/Helmsley and MAA
- A second significant revision of lesson plans

Classrooms Designed for Active Learning

Professional Development for GTAs
An Essential Strategy

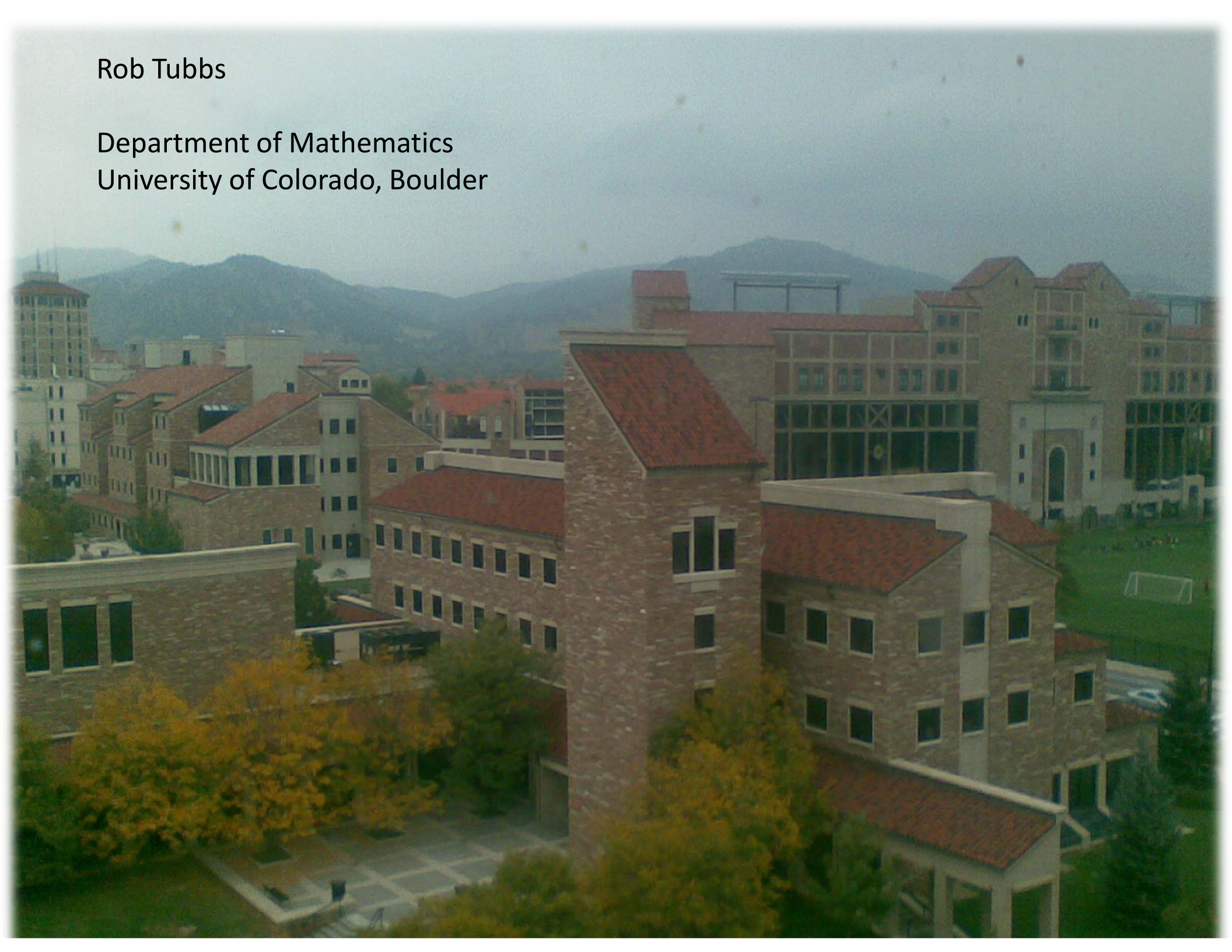
- Intensive week-long workshop in August
- Focused experience in first year of teaching own course
  - Significant classroom observation and feedback on teaching
  - Common lesson plans, course policies, WeBWorK homework, exams written by the Director of First-Year Mathematics, etc. permit GTAs to focus on learning to teach and to develop a positive rapport with the students they teach
- Graduate-level course in Mathematics Pedagogy
  - Text: A Practical Guide to Cooperative Learning in Collegiate Mathematics (MAA)
  - First paper: “Detail your own view of how learning occurs, how it applies to your classroom, and how it compares with constructivism. . . ."

Research initiatives

- Measure student success
  - D/F/W rates as compared with previous student success
  - Student learning as measured by faculty analysis of exams and faculty judgment with respect to standards for earning a grade of A, B or C
  - Student course taking patterns and success in mathematics classes after completing Math 101 or 103.
- Factors that influence student success
  - identify which changes contribute significantly to student success
  - survey students to identify how their attitudes toward mathematics and their perseverance in learning mathematics are impacted by the instructional approach or their own personal successes
- Does the experience impact GTAs teaching practices?

Rob Tubbs

Department of Mathematics
University of Colorado, Boulder



A Brief Outline of the Evolution of Calculus I at Boulder

- 1980s—Taught in 120-student lectures MWF by tenured, tenured-track faculty (with smaller, 30-student Tues. & Thurs. recitations led by TAs)
- Early 1990s—Large lectures replaced by 30 student MTWF classes taught by TA-Instructors with Thurs. recitations taught by TAs
  - Introduced MATH 5905: Mathematics Teacher Training

A Brief Outline of the Evolution of Calculus I at Boulder

- 2007/8 Undergraduate Learning Assistants added to the Thursday recitations
  - -Transformation of the recitations from homework help sessions to group work on projects
  - - Developed worthy projects
  - - Introduced MATH 3850: Seminar in Guided Mathematical Instruction

A Brief Outline of the Evolution of Calculus I at Boulder

- 2013 MTEP supported work began
  - Expansion of active learning from the Thursday recitations to non-recitation class meetings

CU team: David Webb, CU School of Education

Kimberly Bunning, CU School of Education

Faan Tone Liu, CU Math

Eric Stade, CU Math

Rob Tubbs, CU Math

Working with Angie Hodge, U. of Nebraska, Omaha

Active Learning in Action

$h(x) + 1$

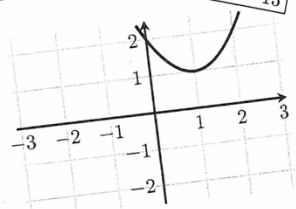
13

$x^2 - 2x + 2$

M

$x^2 + 2x + 1$

N



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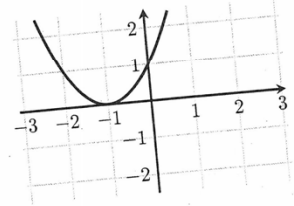
$-h(x)$



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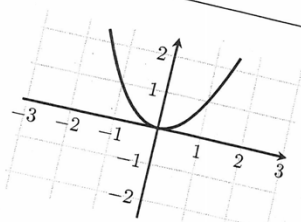


+

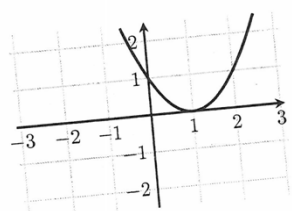
$h(x+1)$

12

$h(-x)$

14

$x^2 - 2x + 1$

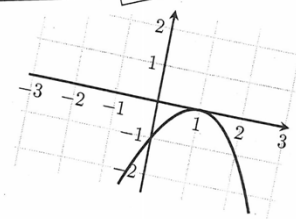


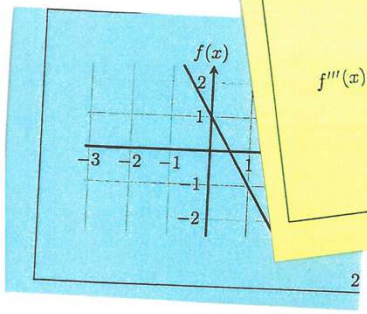
⇒

$-x^2 + 2x - 1$

$h(x)$

x^2





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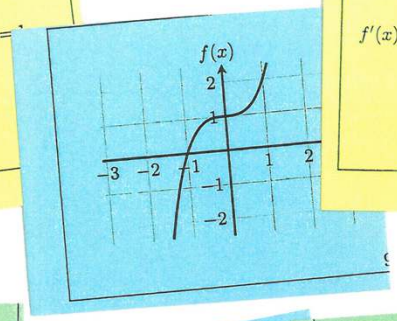
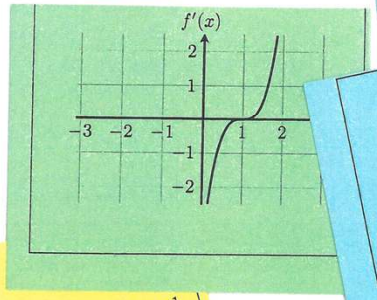
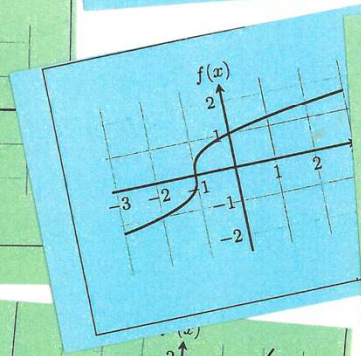
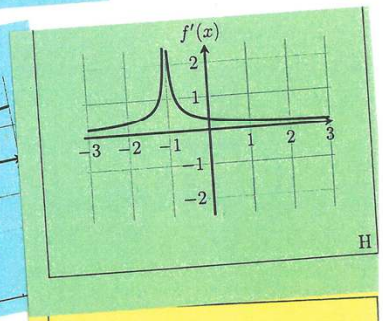
$f'''(x)$ switches signs at $x =$



$f'(x) > 0$ and $f''(x) = 0$ everywhere.



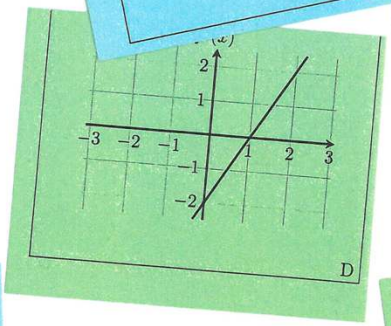




H

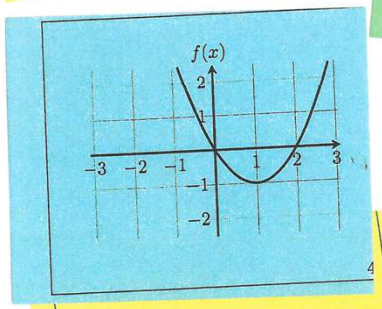
$f(x)$ has an inflection point at $x = 1$ because $f''(x)$ switches signs at $x = 1$.

?



D

$\int_0^1 f'(x)\,dx = 3$



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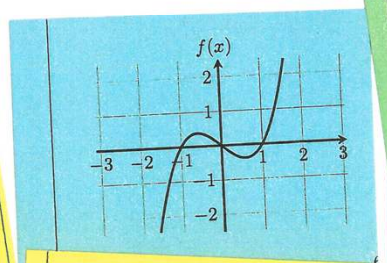

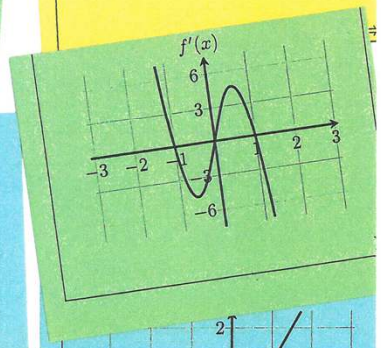

$f(x)$ is always concave down because $f'(x)$ is always decreasing.

□

$\int_0^1 f'(x)\,dx = 1$

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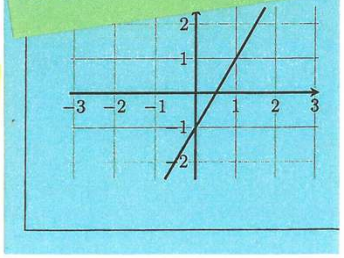

Next Steps

- Revise and/or replace activities used in Fall 2014
- Develop additional materials
- Institutionalize professional development of graduate students
- Disseminate materials

AUBURN UNIVERSITY
ACTIVE LEARNING INITIATIVE

Department of Mathematics and Statistics
College of Sciences and Mathematics

Context

- Piloting active learning strategies in Calculus I and Calculus II beginning Spring 2014
  - Dr. Ulrich Albrecht is the lead and teaches a section of Calculus II
  - Two senior GTAs teach two sections of Calculus I and two additional sections of Calculus II
  - Dr. Gary Martin provides support
- Goal: To build support for expanding use of strategies in additional sections

Approach

- Traditional class arrangement – classes of 28 students meet 4 times per week for 50 minutes.
- Decreased use of lecture and incorporation of group work on challenging problems.
- Use of Learning Assistants to support student interactions on 3 of the 4 class meetings.
- Use of Webassign for homework (on-line).

Professional Development

- Pre-semester meeting with all instructors and Learning Assistants.
  - What it means to learn mathematics
  - Why we need to teach differently
  - Effective questioning
  - Course structure
- Meetings throughout the semester to work to plan and discuss further.

Results from Spring 2014

- Inconsistent changes in DFW rates across sections.
  - Significant proportion of the failures did not attend class.
- However, the overall grade distributions were generally better.

Next Steps

- Continue to implement in the spring.
  - Try one section in a large-lecture format.
- Build additional support for the approach among administrators.
- Recruit additional faculty members to become involved.

Table Discussions

- What changes might work on your campus?
- What information would you need to advance the issue on your campus?

QUESTIONS AND DISCUSSION

For more information:
www.MTE-Partnership.org