The Impact of STEM Education Research at UMass Dartmouth

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Our identity

- What is STEM Education?
- STEM Department
- Kaput Center for STEM Research and Innovation in Education
- An evolution of over three decades of work
Interdisciplinary department focused on the integration of Science, Technology, Engineering, and Mathematics

Responsible for serving K-12 educators seeking an initial or professional license as teachers of Math, Biology, Chemistry, Physics, or General Science and provides STEM courses in the appropriate tracks of the MAT (Master of Arts in Teaching) Program

Deliver newly approved Ph.D. in Mathematics Education.

The department endeavors to strengthen the quality of STEM research and education, as well as advance the University's STEM related partnerships with schools and industry
Kaput STEM Center

• Over $10m in federal funding in the past 10 years of national and international impact

• **Classroom wireless connectivity** - Use of SimCalc MathWorlds software on graphing calculators and desktop computers to improve teaching, learning and participation in algebra and pre-calc classrooms in collaboration with 8 SE MA districts & Texas Instruments - US ED (IES) funded

• **Dynamic Haptic Geometry** - touching and feeling mathematical & scientific concepts in elementary schools - NSF funded

• **Scaling up use of SimCalc software** in 150 schools (inc. 8000 students) in Texas in collaboration with SRI International - NSF funded

• **Improving teaching & learning, grades 4-8** in collaboration with Wareham/Carver school districts - MMSP Title II-B funded, MA Department of Education

• **Teaching and Learning Algebraic Thinking** in the Elementary Grades - NSF funded

• **Undergraduate’s understanding of proof** - Teaching and Learning Mathematical Proof Across Grades K-16 - NSF Funded
Time to move from research to practice & policy at scale!
Big Problems

- Algebra Problem (RAND Report 2002)
- Student motivation and alienation in the nation’s schools, especially urban secondary schools (National Research Council, 2003)
- Widely acknowledged unfulfilled promise of technology in education, especially mathematics education (e.g., Cuban, 2001)
Exhibit ES-1. Percentage of Students With Access to Computers for Mathematics Instruction in 2004–05

In classroom
- Grade 4: 55%
- Grade 8: 44%

In computer lab/media center
- Grade 4: 74%
- Grade 8: 79%

Students do not use computers in mathematics
- Grade 4: 30%
- Grade 8: 36%


There was variability among states in students' access to classroom computers in 2004–05. In some states, 20 percent or more of fourth- and eighth-grade students were in mathematics classrooms with computers; in other states, 60 percent or more of fourth- and eighth-graders were in mathematics classrooms that had computers (Exhibit ES-2).
Exhibit ES-3. Percentage of Students Whose Teachers Used Computers in Mathematics Instruction at Least Once a Week in 2004–05

- To present mathematics concepts:
  - Grade 4: 9%
  - Grade 8: 13%

- To post homework, assignment, or schedule information on the Web:
  - Grade 4: 11%
  - Grade 8: 32%

Primary Focus of STEM in MA

- STEM Workforce/Pipeline initiatives
- Increase numbers of students from schools into higher education programs
- Increase economic productivity of the commonwealth
- STEM Accelerated College enrollment
- Teacher Quality - MSP
Critique

• How can a K-16 Regional Network accomplish this?

• In addition to professional development (Title II funded projects; MSPs etc) what more is needed?

• Where is research and innovation in these projects?

• We are in the business of nurturing creative minds.
Gap Analysis: where we fill it

Given what we are doing now as a region, where have gaps been identified?

- Student interest still needs to be strengthened
- Need for a speaker bureau/speaker database
- Low participation in science fairs
- Need more visits from STEM businesses to campuses and schools
- Excitement gap exists
- Gap exists with communication to parents
- PreK-12/Higher education gap still exists
- No website link directed at students/parents
- Not enough linkage with museums and other non-profit sector

From SE STEM Regional Network Strategic Plan’08
Motivation

- Extrinsic motivation such as rewards can have an undermining effect and decrease intrinsic motivation
- Intrinsic motivation reflects the propensity for humans to engage in activities that interest them
- Key factors for participation but have been orthogonal to the field of inquiry to the development and instruction of content
- Motivational strategies have been in the form of incentivizing students because it is fun
A new approach

• Students can be motivated because they want to participate more fully in what their classroom is doing now

• Link motivation and mathematics through participation

• But before we say we just need new technology ....
The development of portability of information and knowledge

Clay
↓
Papyrus
↓
Paper
↓
Screen

Beginning of the history of malleability of media as part of man’s efforts to evolve communication acts
From Static to Dynamic Mathematics

What happens with mathematics when it is transcribed/embedded in a digital media?

Is its mode of existence the same?

Are new mathematical phenomena waiting to be represented?

This transcription cannot simply be described as one whose end result is:

to provide the thinker, the teacher, the student, with a more convenient amplifying device.

Technology should not serve as a prosthetic device to prop up old practices but transform the educational landscape.
What have we done?

1. Software & Curriculum are inextricably linked

2. Students participation are mathematically meaningful

3. Agency is distributed

4. Feedback is collaborative and non-verbal - enhancing metacognition

5. Mathematical structure as emergent phenomenon - students build reasoning and abstraction gradually

6. Co-action - guiding and being guided by the environment
Our uniqueness

• Long history of cutting-edge R&D
• Integrated “trans”-disciplinary work
• Efficacy and effectiveness trials
• Tenured, internationally renowned faculty with content specialization
• Niche, cutting-edge programs in mathematics, science and technology education
• Broad, international network base (local to global)
• Integration of department and research center to create novel programs for teachers and scientists, new creative minds, authentic learning experiences – from research to practice
Empirical Results
Quasi-Experimental Study

- 3-6 week replacement unit on core Algebra concepts: linearity, slope as rate, function, y=mx+b
- 9th grade Algebra 1 classrooms in two middle-achieving districts in SE MA
- Initial sample: Comparison (217 students), SimCalc (156 students)
- Final sample: Comparison (184 students), SimCalc (133 students)
- SimCalc: 7 classrooms (5 teachers) in 2 districts
- Comparison: 8 classrooms (8 teachers) in same districts
Methods

- Mathematics Algebra 1 Content Test
- Student Attitude Survey
- Student and Teacher Interviews
- Classroom Observation: Video + Structured observation (e.g. RTOP)
- Lesson Study
Content

- A total of 60 test items were compiled from various state high stakes assessment tests, such as the Massachusetts Comprehensive Assessment System (MCAS), Texas Assessment of Knowledge and Skills (TAKS), Regents Exam in New York, and the California High School Exit Examination (CAHSEE), as well as National Assessment of Educational Progress (NAEP) items, and Advanced Placement Calculus items.
- Reduced to 22 items via principled-assessment design.
- 20 multiple-choice; 1 short answer; 1 open-response.
- 12% of tests checked across 3 raters (inter-rater reliability of 92%).
- Four sub-scales: Graphical interpretation (41% of the test), Rate and proportion (22.7%), Number sense and patterns (4.5%), and Making connections across representations (31.8%).
Overall Gains

- Pre-to Post, there was a significant learning gain for the SimCalc group (M=1.99, SD=3.535) compared to the Comparison group (M=0.96, SD=3.301).
- This group difference is statistically significant, \( t(322)=2.711, p=0.007, d=0.30 \) (\( r=0.15 \))
- Gains on only the multiple-choice items, 20 of the 22 items, reveal a greater significant difference between groups, \( t(322)=3.069, p=0.002 \). This represents a medium effect, \( d=0.34 \) (\( r=0.17 \))
Comparison class C7 and SimCalc class C12, are both Honors classes taught by the same teacher. There is not a statistically significant difference between these two classes on the pre-test, $t(44)=0.236$, $p=0.815$. While a learning gain occurred in both classes, the SimCalc class had a significantly greater learning gain than the Comparison class, $t(40)=-2.242$, $p=0.031$. This represents a medium to large sized effect, $d=0.7089$. 
Teacher Interview

• There were a lot of things I was taking [from his SimCalc class and into his Comparison class] it wasn’t what we did technology-wise, it was the base model they [the SimCalc kids] had for position versus time, I took a lot of that stuff and brought it over [to my Comparison class]. It just made things more concrete, a lot clearer for the students [in the Comparison class].” When asked about the discussions that occurred in his SimCalc class compared to his Comparison class, the teacher stated: “I liked letting them [SimCalc students] take over the discussion because they always have that example [SimCalc] to go back to. It’s harder when they only have the abstract. [My Comparison class] couldn’t verbalize what they needed to… They could explain why after but they wouldn’t be able to express it themselves and in their own words.”
Multiple Representations

- SimCalc students have a significantly greater gain than the comparison group on multiple representation items $t(322)=-4.771$, $p<0.0001$ which represents a medium sized effect, $d=0.53$.
Gender

- SimCalc Males and Females gain significantly more: females: $t(160)=4.442$, $p=0.000$; males: $t(160)=2.076$, $p=0.039$
- SimCalc Females gain (1.93) significantly, and are sig. different from SimCalc males (1.14) $t(135)=2.65$, $p=0.009$
Student Attitude

An Attitude Model derived from a previous study yielded 4 constructs via Factor Analysis:

1. Positivity towards math and school (α = .717)
   • “I think mathematics is important in life.”

2. Working collaboratively & related affect (α = .692)
   • “I sometimes feel nervous talking out-loud in front of my classmates.”

3. Working privately (α = .727)
   • “I learn more about mathematics working on my own.”

4. Technology (α = .674)
   • “Technology can make mathematics easier to understand.”
• No significant correlations with the comparison class
K-16 Regional STEM Network

• Focused on creating a regional “Professional Learning Community”
• Establish a regional database to evaluate performance, needs and effectiveness of implemented programs (needs support)
• Connect faculty, teachers and administrators to establish mutually beneficial R&D programs
What we need from you to evolve?

• Leverage our work
• Help us understand how to move from research to practice
• How do we impact policy at a local level (superintendents); regional (MA) and National.
• What niche-programs can support our work and collaborators
• Where do we fit in at a national scale
Thank You!

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