Implementing Active Learning in Undergraduate STEM Courses

Jessica Rosenberg, Ph.D.
Wendy Smith, Ph.D.

This material is based upon work supported by the National Science Foundation (NSF) under Grant No. DUE-1937267. Any opinions, findings, interpretations, conclusions or recommendations expressed in this material are those of its authors and do not represent the views of the AAAS Board of Directors, the Council of AAAS, AAAS’ membership or the National Science Foundation.
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Implementing Active Learning in Undergraduate STEM Courses

Jessica Rosenberg
George Mason University

NSF IUSE ICT 1821589: Building a Culture of Active Learning through Course-Based Communities of Transformation
Leadership Team

Jessica Rosenberg  
Physics and Astronomy

Jaime Lester  
College of Humanities and Social Sciences

Mark Snyder  
Computer Science

Jill Nelson  
Electrical and Computer Engineering

Bob Sachs  
Mathematics

PhD Students

Julie Shank  
Higher Education Program

Kat Fernandez  
Physics and Astronomy

Phoebe McClincy  
Physics and Astronomy

Program Manager: Melinda Ryan
A Large Fraction of Students Leave STEM
A Large Fraction of Students Leave STEM

**NOW: Talking about Leaving Revisited (2016): What Factors Contribute to Switching Decisions?**

<table>
<thead>
<tr>
<th>Factors Contributing to Students' Decisions to Switch from a STEM Major that also Affect Non-switchers</th>
<th>% Switchers (N=96)</th>
<th>% Non-switchers (N=250)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor grades</td>
<td>61%</td>
<td>14%</td>
</tr>
<tr>
<td>Lost interest in or disappointed by STEM major</td>
<td>61%</td>
<td>5%</td>
</tr>
<tr>
<td>Lacks sense of belonging, negative culture of STEM</td>
<td>52%</td>
<td>8%</td>
</tr>
<tr>
<td>Problems with classroom learning experiences (too fast pace, course pitched too high; poor alignment between course elements)</td>
<td>51%</td>
<td>16%</td>
</tr>
<tr>
<td>“Weed-out” effects from gateway STEM courses</td>
<td>33%</td>
<td>15%</td>
</tr>
<tr>
<td>Under-informed, wrong choice of STEM major</td>
<td>42%</td>
<td>6%</td>
</tr>
<tr>
<td>Poor high school preparation, difficult transition to college</td>
<td>38%</td>
<td>3%</td>
</tr>
<tr>
<td>Career-choice limitations</td>
<td>33%</td>
<td>4%</td>
</tr>
<tr>
<td>STEM major too narrow: Wants to broaden education</td>
<td>26%</td>
<td>2%</td>
</tr>
<tr>
<td>Problems with poor quality of teaching</td>
<td>25%</td>
<td>2%</td>
</tr>
<tr>
<td>Difficulties getting help</td>
<td>21%</td>
<td>8%</td>
</tr>
<tr>
<td>Working a lot of hours/full-time makes succeeding in a STEM major too difficult</td>
<td>3%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Anne-Barrie Hunter, Heather Thiry, Dana Holland, Raquel Harper, Elaine Seymour
Project Goals

• Use multi-generational teams to spread the culture of active learning within the STEM faculty and facilitate broad adoption.

• Develop an understanding of how a faculty-driven grassroots approach, combined with institutional support, can build a culture of active learning.

• Study strategies to remove barriers for faculty implementing new evidence-based teaching methods.

• Prepare the next generation of STEM educators by involving graduate and undergraduate students in the implementation of active learning in the classroom.
Grassroots Change

• Grassroots leaders seek to change their institutions from within

• Effective tactics include organizing intellectual opportunities, professional development opportunities, leveraging curricula and classroom as a forum (Kezar and Lester 2011)

• Change requires altering individual mindsets or perspectives, including those of campus leadership (diffusion)
Who are your change leaders?

• What are the most important qualities of a change leader?
Project Implementation

• Mason is a large (38,000), public, very high research activity university
• Focused on large-enrollment intro. courses
• Implementation in Math (Calc I & II), Physics (University Physics I & II), and Computer Science (Intro)
  • Math: Launched Early 2019
  • Physics: Launched Fall 2020
  • Computer Science: Launched Fall 2021
• Faculty determine active learning emphasis (grassroots)
• Disciplinary leads facilitate efforts
Project Implementation: Launch workshop

• All-day workshop
• Morning: setting the institutional stage and explaining why active learning is important in the discipline
• Afternoon: faculty collaboration and planning change efforts
Common Themes

- Restructure recitations to make them student-centered
- Improve course coordination
- Build or borrow materials that will support active learning
- Provide GTA training/support

Which of these themes are most resonant for you, in your circumstances?
Prepare the next generation of STEM educators by involving graduate and undergraduate students in the implementation of active learning in the classroom

• Physics GTA seminar

**Structure:** Weekly seminar written into the contracts for all physics and astronomy GTAs. First-year graduate students meet weekly to discuss issues in their classes, learn more about active learning, and build a community and a discourse on teaching. Faculty led.

• Math GTA training

**Structure:** Weekly meeting of Calc I & II GTAs to check in, discuss issues in their classes, learn more about active learning, and build a community and a discourse on teaching. Two GTA leaders facilitated discussion

• Learning assistant seminar

**Structure:** Weekly meeting of new LAs across College of Science to discuss issues in their classes, learn more about active learning, and build a community and a discourse on teaching.
Results of GTA Efforts

• Preparing GTAs to use student-centered practice takes time and/or direct guidance
  • Repeat discussions helps solidify ideas in new instructors
  • Creating and executing student-centered activities can be instructive and fun for more advanced GTAs

• Building community among GTAs provides opportunities for deeper, more challenging discussions.
  • Peer-to-peer discussions builds trust and engages GTAs in examination of their own practice

• GTAs are future faculty - if STEM teaching is to change, we must help them learn new techniques
Use multi-generational teams to spread the culture of active learning within the STEM faculty and facilitate broad adoption

How?

• Create teams of faculty, GTAs, and LAs focused on implementing active learning in targeted gateway courses

• Build course-based communities of transformation (CCTs) within Math, Physics, and CS

• Provide training on active learning and organizational change in higher education
Use multi-generational teams to spread the culture of active learning within the STEM faculty and facilitate broad adoption

- Regular meetings of engaged faculty
  - Math alternates discussion with a seminar on education research
- Engagement across generations depends on course structure
  - Hard in general
  - Very hard during a pandemic
Develop an understanding of how a faculty-driven grassroots approach, combined with institutional support, can build a culture of active learning.

Mason is supporting increased active learning: The current strategic plan aims for 30% of all classrooms being Active Learning Classrooms. The accelerator works to support College of Science faculty teaching in these spaces through learning assistants and faculty development.
Collaboration and Diffusion are important

- Active Learning Brown Bags
- Collaboration between CCT leads
- Discussion with campus leaders
- Connection to institutional goals
Final Thoughts

• Institutional and disciplinary norms shape path
  • Even access to collaborative learning spaces has gotten more difficult with rising research status
• Helping graduate students learn new techniques is an easy gateway to improvement
• Developing resources for active learning can help support efforts
• Doing this work highlights areas where coordination is needed and highlights the need for coordination work
• Pandemic and remote teaching makes all of this harder but also has allowed new leaders to emerge
Questions to consider

• What do you see as the levers for changing the culture of teaching particularly with respect to large introductory course? What are the challenges or barriers?

• How do we make these efforts and changes sustainable?
Departmental Transformation to Improve Student Success in First-Year Mathematics Courses

Dr. Wendy M. Smith
University of Nebraska-Lincoln
AAAS Webinar, 26 October 2021

SEMINAL is supported by a grant from the National Science Foundation (DUE-1624643, 1624610, 1624628, and 1624639). All findings and opinions are those of the authors and not necessarily of the NSF.
1. Learn about change levers from SEMINAL
2. Consider the role of policies in change efforts
3. Consider a systems-thinking approach to policies & change
4. Discuss how to apply findings
What is the Problem?

- 95% of students in college math are taking courses at/below Calc 2 (3.2M)
- Average of 25% DFW at R1 institutions in Calculus (often closer to 50%)
- Failing math correlates highly with freshman dropouts
- After freshman year, students switch away from STEM majors (9-25%)
- Beliefs about & attitudes toward mathematics K-20 follow a decreasing trajectory
How Do People Learn?

Teach others
Do the math
Discuss & critique
Observe demonstration
Listen
Read

Amount of Learning

How does this align with how we teach?
What is “Active Learning”? 

Teaching methods and classroom norms that promote:

1. Students’ deep engagement in mathematical reasoning
2. Peer-to-peer interaction
3. Instructor interest in and use of student thinking
4. Instructors’ attention to equitable and inclusive practices

Laursen and Rasmussen (2019)
Undergrads in active learning environments can learn more effectively, resulting in increased achievement and improved dispositions (Freeman et al., 2014; Laursen et al., 2014; Rasmussen & Kwon, 2007), particularly for underrepresented groups (Laursen et al., 2011; Theobald et al., 2020).
An n-dimensional problem \((n>2)\) cannot be solved with a 1- or 2-dimensional solution

- Systemic approach needed to address the system that created/perpetuates current problems
- Cultural change is needed for a dept to shift away from lecture as the norm
- Cultural change encompasses people, power, structures, & beliefs
Effective Change Process

Assumptions
1. Start by developing a common vision of “success”
2. All relevant stakeholders are involved
3. Change is complex
4. Need “change agents”
5. Mathematical rigor is important
Goal: better understand how to enact and support institutional change aimed at implementing active learning in undergraduate mathematics learning environments

Collaborative Research: NSF I-USE Grant

- $3.6 million, 2016-2022
- APLU
- University of Colorado Boulder
- University of Nebraska-Lincoln
- San Diego State University
- Phase 1: 6 cases of retrospective change
- Phase 2: 9 cases of incentivized change
- Phase 3: 12 cases of networked change
- AMS/MAA/CBMS handbook (May 2021)
### Retrospective, Longitudinal & Ongoing Case Studies

<table>
<thead>
<tr>
<th>Self-Study</th>
<th>Local Data</th>
<th>Observation</th>
<th>Interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P2C2 student demographics</td>
<td>Observe P2C2 courses</td>
<td>Administrators</td>
</tr>
<tr>
<td></td>
<td>DFW rates</td>
<td></td>
<td>Department leaders</td>
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<tr>
<td></td>
<td>Course-taking trajectories</td>
<td></td>
<td>P2C2 Coordinators</td>
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<tr>
<td></td>
<td>Placement</td>
<td></td>
<td>Faculty Instructors of P2C2</td>
</tr>
<tr>
<td></td>
<td>Retention</td>
<td></td>
<td>Undergraduate Learning Assistants</td>
</tr>
<tr>
<td></td>
<td>P2C2 Instructor Survey</td>
<td></td>
<td>Students in P2C2 courses</td>
</tr>
<tr>
<td></td>
<td>P2C2 Student Survey</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Phase 1 retrospective cases**: 6 site visits - Spring 2017
  - Handbook coming April 2021
- **Phase 2 longitudinal incentivized cases**: 9 sites x 3 site visits 2018-2021
  - PRIMUS special issue online (2020)
- **Phase 3 ongoing case studies**: 12 sites (virtual visits)
Seeing the System
SEMINAL hypothesis

Department

- Faculty Task Force
- Administrative Leadership
- P2C2 Coordinators
- Physical Resources
- Student Placement
- Instructional Commitment to ALM
- Access to Local Data
- Faculty/GTA Training
- Student Academic Support

Classroom

- Activities and Tasks
- Peer-to-Peer Interaction
- Norms for Discourse
- Teacher Inquiry into Student Thinking
- Mathematical Coherence
- Instructional Decisions and Assessment
Critical features of transformed institutions:
- Institutional & community identities
- Campus culture with respect to teaching
- Effective leadership (opportunistic)
- Willingness to pay the costs of improved instruction
- Coordination of multi-section courses
- Sufficient support for enacting new pedagogies
- Flexibility
- Plan for succession/enculturation of people
SEMINAL Phase 2 - Local Change Strategies

- Initiate & expand course coordination (including assessments)
- Hiring (course coordinators, learning assistants; instructors)
- Instructor professional development
- Local data & course placement
- Active learning tasks & materials
- Culturally responsive teaching
- Planning for sustainability
Levers for Change

Improve Student Outcomes

Involvement of:
- Campus administrators for undergraduate education (provost & dean levels)
- Chair & Vice Chair
- Faculty Task Force
- Course Coordinators
- Math Ed Researchers
- Instructors (faculty, adjunct, grad)
- Learning Assistants
- Students
- Access to university data system (student demographics, major, retention, graduation)
- Attendance (class, Learning Center)
- DFW rates & enrollment
- Course-taking trajectories (subsequent grades)
- Student surveys (beliefs, perceptions)
- Focus group interviews (students, instructors)
- Instructor survey, interviews
- Observation (coordinators, peers)
- Assessments (homework, exams, item-level)
- Department culture, instructor networks
Leadership

- Dept chair committed to efforts
- Faculty committee to drive and sustain reforms
- Align to university efforts
  - Freshman retention; graduation rates
  - Campus administrators’ priorities
- Coordinators
  - Semi-permanent
- Plan for sustainability
- Plan for turnover & bringing new people on board
In most classes
• Group work for majority of time
• Class time focuses on application problems
• Mini-lectures for 5-10 min as needed
• Instructor (+ Learning Assistant)

In large lectures
• Clicker questions to prompt discussions
• **Common course activities**
  - Worksheets
  - Course Packets

• **Assessment**
  - Homework
  - Quizzes
  - Exams/Midterms

• **Textbook/OER**

• **Messaging to students & instructors**
• Syllabus
• Textbook (OER)
• Lesson Plan Repository
• Course Packets/Worksheets
• Homework (e.g., WeBWoRK)
• Exams (Midterms & Final)
  • Common Grading (e.g., Grade Scope, Crowdmark)
• Weekly instructor meetings
  • Begin prior to semester
  • Anticipating student misconceptions
• Pre-Semester
• Weekly
  • Instructor meetings
• Dept Teaching Seminar
  • Faculty & grad students
• Travel to workshops (IBL)
• Pedagogy Course for GSI/LA
“While it may be tempting to simply authoritatively state the correct order in which to perform horizontal transformations, doing so effectively removes ownership of knowledge from students, and encourages them to view mathematics as a set of arbitrary rules to be applied blindly. By removing ownership from students, we ultimately discourage students from building their own base of knowledge surrounding the topic.”

--Precalculus Instructor
• **Textbook**
• **Lesson Plan Repository**
  contribute revisions, worked examples
• **Weekly instructor meetings**
• **Advice networks for teaching and learning**
Learning Assistants

- Support group work
- Training in supporting active learning
- Meet with instructors weekly
  - Reflect after class
- Recruited from math majors & ‘A’ students in courses with learning assistants
Learning Environment

- Dedicated, renovated classrooms
- Tables & chairs
- Whiteboards all around
- More time (50 - 75 min)
Useful Resources

SEMINAL book


https://www.tandfonline.com/toc/upri20/31/3-5?nav=tocList

https://bookstore.ams.org/mbk-138/?_zs=L5oRC1&_zl=rSpG6
Useful Resources

Accelerating Systemic Change Networks (ASCN) information on transforming institutions

ASCN Change Dashboard
https://ascnhighered.org/ASCN/change_dashboard/index.html

https://ascnhighered.org/ASCN/publications.html
Useful Resources

Practical plan for starting changes (checklists, inventories)


Teaching for Prowess
--Project focused on 2-year colleges and active learning

https://teachingforprowess.wordpress.com/
Opportunities for Continued Engagement

• Accelerating Systemic Change Network
  • https://ascnhighered.org/index.html

• Online communities
  • COMMIT Network https://www.comathinquiry.org/
  • MAA CONNECT https://connect.maa.org/home
  • AMATYC Communities https://my.amatyc.org/communities/allcommunities

• MSRI CIME 2021 (2022)
  • full in-person CIME March 16-18, 2022
    https://www.msri.org/workshops/1001
Discussion Questions

- What are the most dominant aspects of your system context related to student outcomes in STEM courses?
- What are your campus policies and cultural norms around educational innovation?
- How might you use change levers to make progress toward improvement goals?
Questions?

Student Engagement in Mathematics through an Institutional Network for Active Learning

SEMINAL

University of Colorado Boulder
Nebraska University of Nebraska-Lincoln
San Diego State University

seminal@aplu.org
wsmith5@unl.edu
Facilitated Breakout Rooms:

1. Navigate to the bottom of your screen and click “Breakout Rooms” button
2. Self-select into your breakout group based on your topic interest and last name

*Note: If you do not see the Breakout Rooms button, please post in the chat to ask to be placed in a breakout room.*
Discussion Breakout Room Recap

Jessica Rosenberg
Phoebe McClincy
  Julie Shank
Wendy Smith
Rachel Funk
Antonio Martinez
Thank you for attending!

Slides and recording will be available later this week.

We value your feedback, please take a few minutes to complete the survey.

@IuseProgram

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