Insights from Two National Studies of Precalculus through Calculus 2

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University of Utah, April 2020

Progress through Calculus (PtC)
Project Overview

Project Goals

- What are the programs and structures of the Precal-Calc 2 (P2C2) sequence as currently implemented?
- What is the relationship between various structural, curricular, and pedagogical decisions (including differing levels of implementation of the practices identified in CSPCC) on student success in P2C2?

NSF I-USE Grant

- 5-year, $2 million, 2014-2019
- MAA (Mathematical Association of America & CBMS; David Bressoud, Rachel Levy)
- San Diego State University (Chris Rasmussen, Matthew Voigt, Antonio Martinez)
- Colorado State University (Jessica Hagman, Jessica Gehrtz)
- Portland State University (Sean Larsen, Kristin Vroom, Tenchita Alzaga Elizondo, Brittany Ellis)
- Estrella Johnson, Virginia Tech
- Naneh Apkarian, Western Michigan University

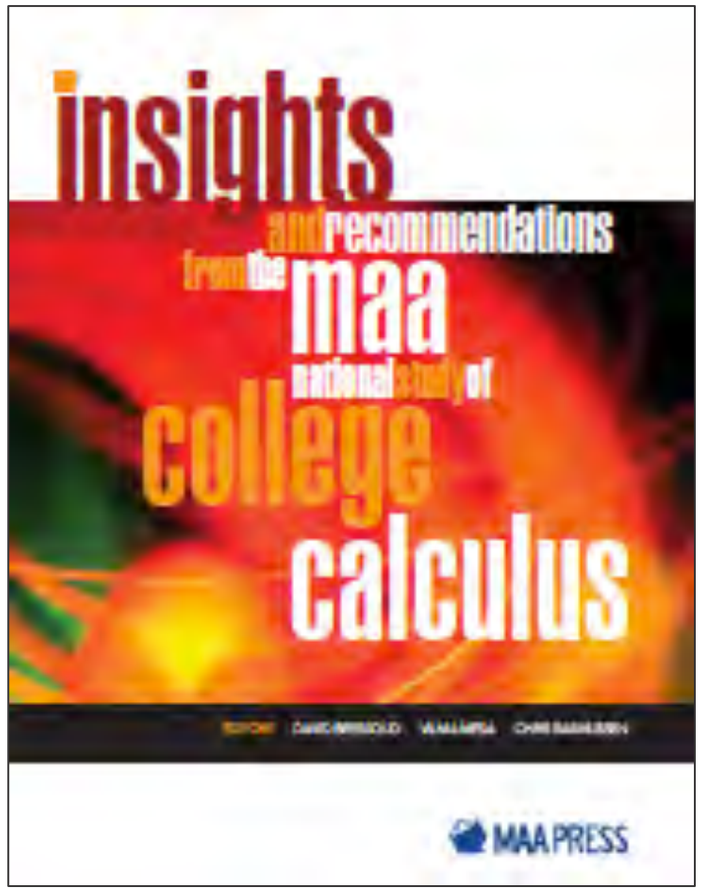
PtC Census Survey

- Identified the 330* university departments that offer graduate level degrees in mathematics
- Overall 67.6% response rate (223/330); 75% of PhD (134/178) and 59% of MA/MS departments (89/152)
- Three part survey:
  (1) List of all Precalculus through Calculus 2 courses (P2C2)
  (2) Department practices in support of P2C2 courses
  (3) Precalculus & Calculus course details (enrolment, DFW rates, instructional approach, etc.)
- **Part (2) based on characteristics of successful calculus programs**

*Based on MAA contact lists, IPEDS databases, and online investigations.
Bressoud, Mesa, & Rasmussen, 2015

Characteristics of Successful Programs in College Calculus

- Regular use of local data
- Effective Placement procedures
- Coordination goals
  - Consistent learning opportunities
  - Instructor community of practice
- Use of active learning
- Challenging courses
- Robust GTA training
- Student academic support



(PDF available at maa.org/cspcc)

(Rasmussen, Ellis, & Zazkis, 2014)

Census Survey Results

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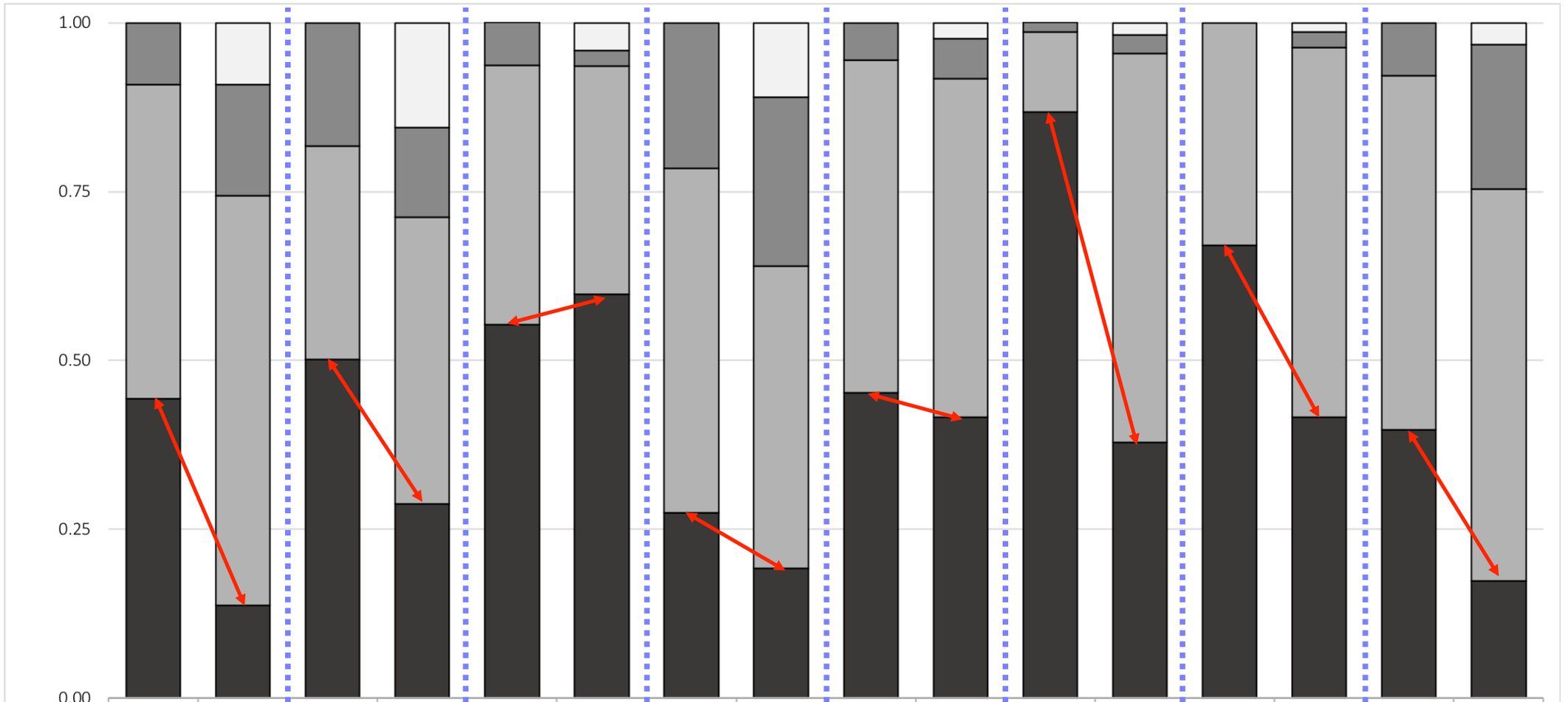
Brief Report

Characteristics of Precalculus Through Calculus 2 Programs: Insights From a National Census Survey

Rasmussen, C., Apkarian, N., Hagman, J. E., Johnson, E., Larsen, S., Bressoud, D. & the Progress through Calculus Project Team

Census Survey Results



	Imp.	Suc.	Imp.	Suc.	Imp.	Suc.	Imp.	Suc.	Imp.	Suc.	Imp.	Suc.	Imp.	Suc.	Imp.	Suc.
	1. Active learning		2. GTA professional development		3a. Uniform course components		3b. Regular instructor mtgs		4. Challenging courses		5. Student placement		6. Student support resources		7. Use of local data	
N.A.		0.09		0.16		0.04		0.11		0.02		0.02		0.01		0.03
Not	0.09	0.16	0.18	0.13	0.06	0.02	0.22	0.25	0.06	0.06	0.01	0.03	0.00	0.02	0.08	0.21
Some	0.47	0.61	0.32	0.42	0.38	0.34	0.51	0.45	0.49	0.50	0.12	0.58	0.33	0.55	0.53	0.58
Very	0.44	0.14	0.50	0.29	0.55	0.60	0.27	0.19	0.45	0.42	0.87	0.38	0.67	0.42	0.40	0.17

Student Engagement in Mathematics through an Institutional Network for Active Learning

Association of Public & Land-grant Universities

SEMINAL

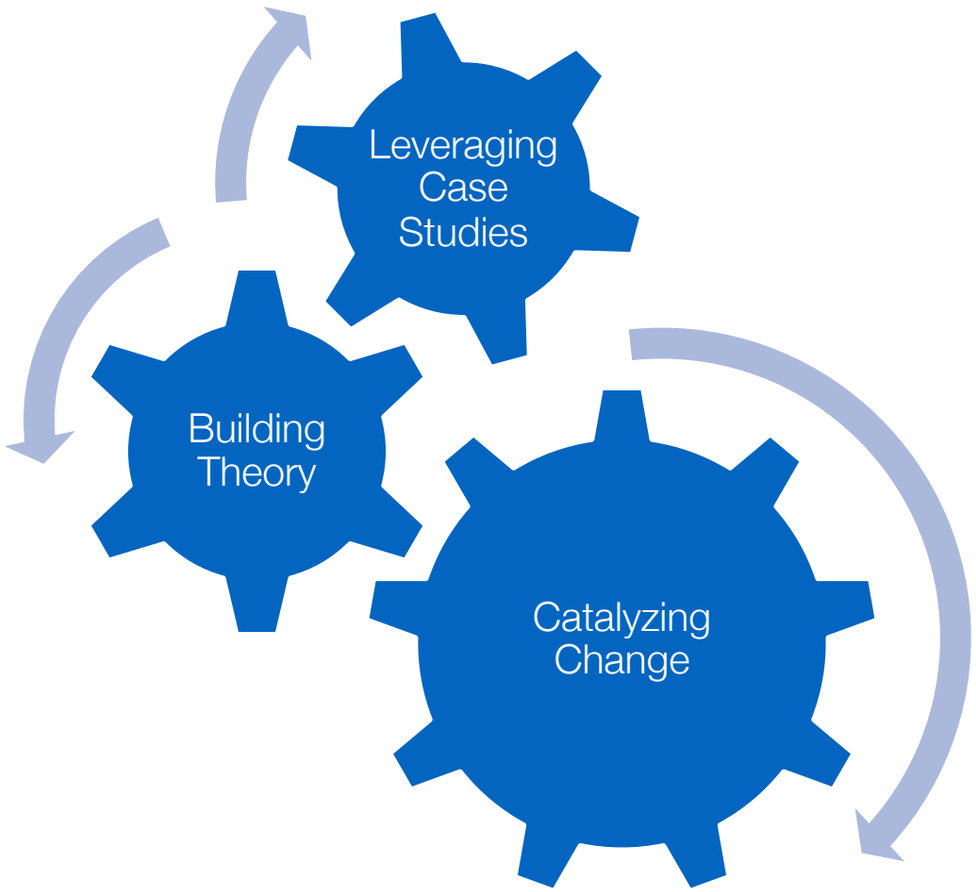
University of Colorado Boulder

NEBRASKA
UNIVERSITY OF NEBRASKA-LINCOLN

San Diego State University

SEMINAL Project

<u>Goal</u>: Better understand how to enact and support institutional change aimed at implementing active learning in undergraduate mathematics learning environments



<u>NSF I-USE Grant</u>

- 5-year, $3 million, 2016-2021
- APLU (Association of Public and Land-grant Universities; Howard Gobstein)
- University of Colorado Boulder (David Webb, Rob Tubbs, David Grant)
- University of Nebraska-Lincoln (Wendy Smith, Allan Donsig, Nathan Wakefield, Rachel Funk, Karina Uhing, Meggan Hass)
- San Diego State University (Chris Rasmussen, Michael O'Sullivan, Matthew Voigt, Antonio Martinez)
- April Strom, Chandler-Gilbert Community College
- Molly Williams, Murray State University

A National Problem

- Average of 25% DFW at R1 institutions in Calculus (often closer to 50%)
- Failing math correlates highly with freshman dropouts
- Beliefs about & attitudes toward mathematics K-20 follow a decreasing trajectory
- Students switch away from STEM majors (40-60%)

Active Learning in Mathematics

Undergrads in active learning environments can learn more effectively, resulting in increased achievement and improved dispositions (Freeman et al., 2014; Laursen et al., 2014), particularly for underrepresented groups (Laursen et al., 2011).

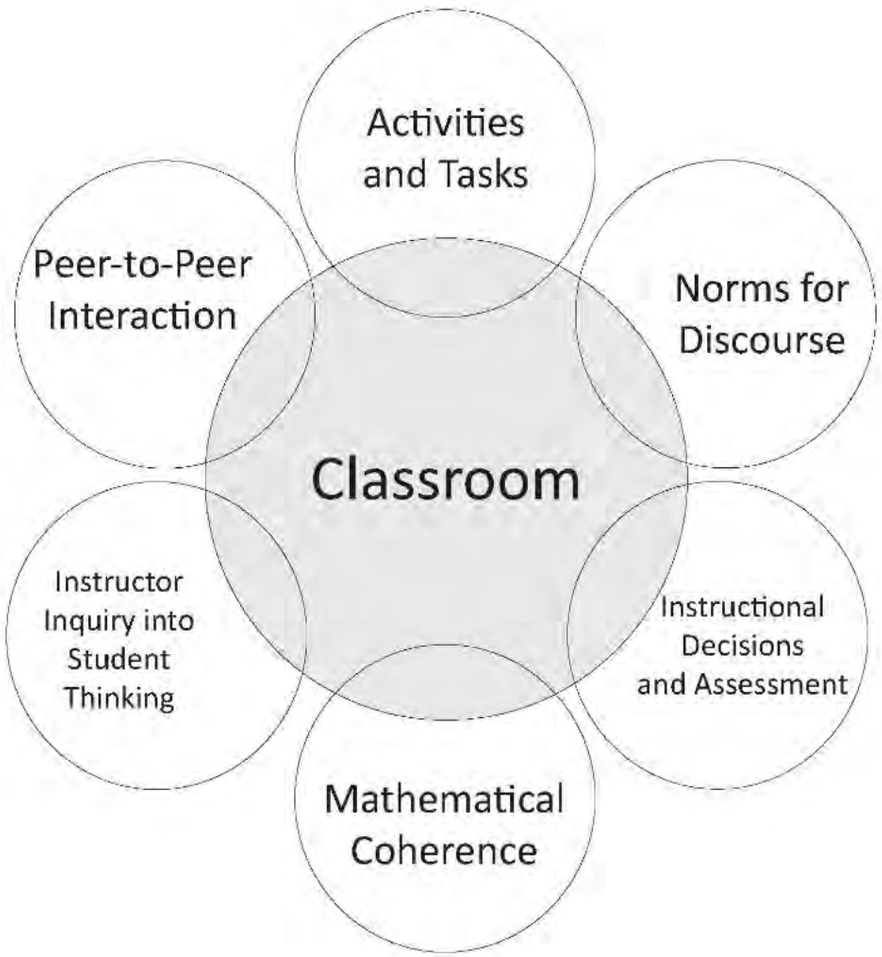
Why aren't strong research findings widely implemented?

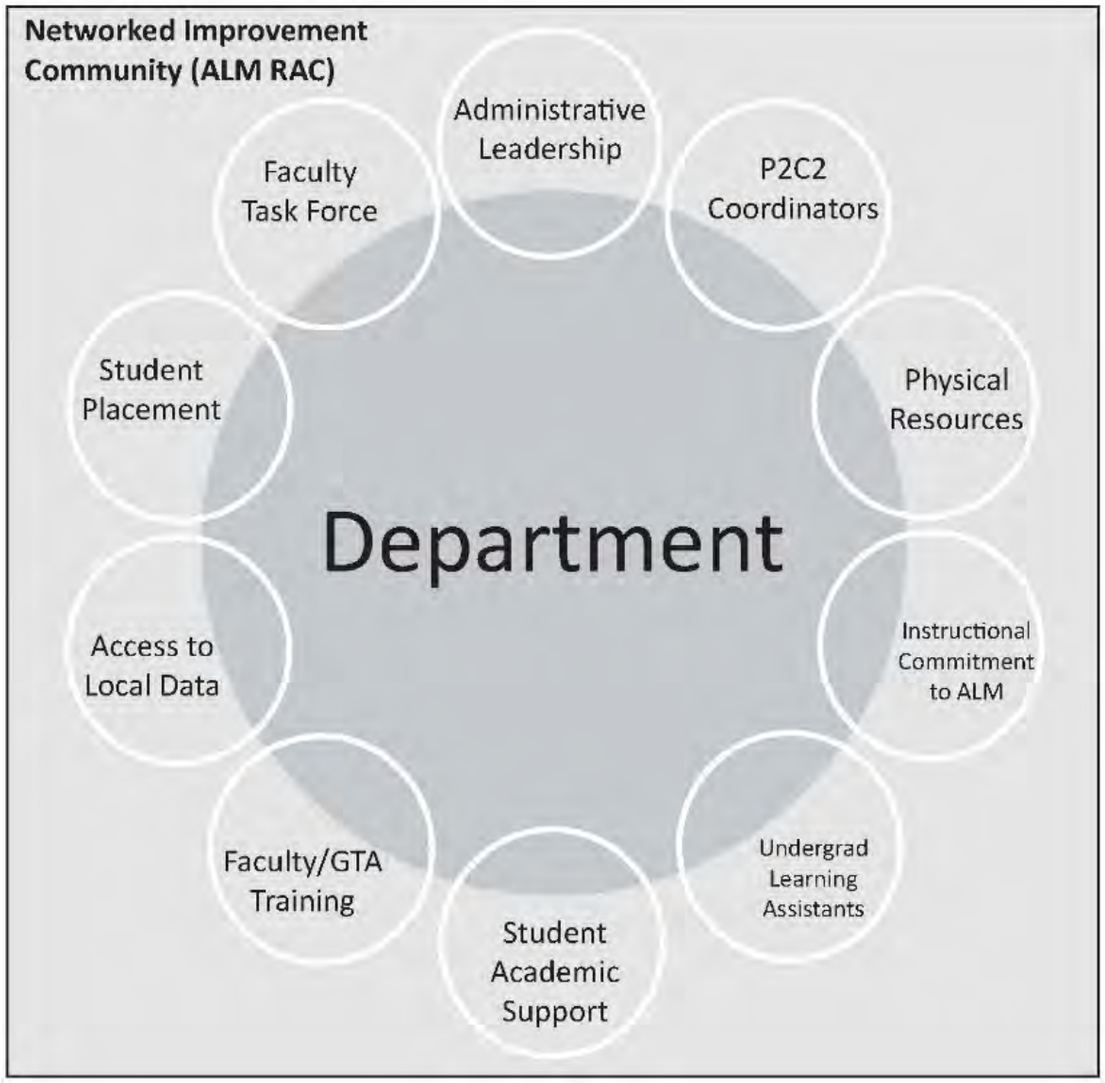
SEMINAL's Take on this National Problem

An n-dimensional problem $_{(n>2)}$ cannot be solved with a 1- or 2-dimensional solution

- No single issue/problem is the sole cause of the current situation
- **A systemic approach is needed for a system that created or perpetuates current problems**
- **Networked Improvement Communities** are a vehicle for systemic & collaborative approaches to education problems

SEMINAL's Comprehensive Approach





SEMINAL Project

Phase 1 – Retrospective change case studies of 6 mathematics departments that successfully implemented active learning in P2C2 courses

Phase 2 – Longitudinal case of 9 mathematics in the process of implementing and sustaining change with a focus on active learning in P2C2 courses

All-in University

Institutional Context

- Approximately 30,000 undergraduates
- Hispanic-Serving Institution
- 84% of full-time undergrads qualify for some type of financial aid
- Around 10% of all bachelor's degrees awarded are in STEM fields
- Approximately 1500 freshmen take a mainstream Precalculus through Calculus (P2C2) course each fall
- 32% of students graduate in 4 years; 66% graduate within 6 years
- Roughly 50% of the students in calculus are engineering majors; 25% are science majors; 10% are mathematics or statistics majors
- Calculus taught in large lecture with recitation sections
- 17 mathematicians (3 in partial retirement, 7 statisticians, 6 mathematics educators)

P2C2: Before and After

Features of Successful Programs	Before	After
Regular use of local data	Nope	Collecting and analyzing
Effective placement procedures	Not so much	Changed to ALEKS
Uniform course components	Zilch	Many
Regular instructor meetings	Only to complain	Some progress
Use of active learning	What is that?	In discussion sections
Robust GTA training	Here's the book	Big progress here
Student academic support	Cramped room	Brand new facility

Local Data – Baseline Information

Funding for a graduate student assistant to analyze data from 2010-2015 was provided by the Provost's office and then the Dean of Undergraduate Studies.

<u>Key Findings</u>

- Typical pass rates for P2C2 courses ranged between 60% and 70%, and approximately 2/3 of these students continued on to the next course
- The proportion of students who started with Precalculus and passed Calculus 2 was roughly 17%, and fewer than 10% did so in three semesters
- Students who failed a P2C2 course were almost doomed

Local Data – Moving Forward

<u>New Questions</u>

(1) How are different demographic groups succeeding (e.g., gender, ethnicity, major, commuter status)?

(2) Why do AiU students leave the STEM pipeline, and where do they go?

(3) What interventions are most successful in supporting struggling students?

Placement – Switched to ALEKS

Benefits of ALEKS

- The questions, which are different each time, require numeric, symbolic, and graphical input, not just multiple choice;
- The AI probe and reporting of the precalculus knowledge gives valuable information to both students and the department, as well as opportunities for students to review

Challenge in implementing ALEKS

- Required coordination with several institutional bodies
- Several logistical hurdles to overcome

Course Coordination – Uniform course components and Regular instructor meetings

Before their change efforts, AiU had **no** coordination of the P2C2 courses – not even a standard textbook. Each of the three courses now has a uniform syllabus, textbook, online homework system, exams (midterms and final), lab activities, and a common grading scheme.

Benefits

- Each course has a coordinator who is taking responsibility for the course as a whole, including organizing instructors and TAs and working with them to develop all course materials
- Faculty have pedagogical autonomy
- Students can more readily work with peers in different sections
- Better horizontal and vertical coordination
- Regular instructor meetings are beginning to engender a sense of community in the department surrounding the P2C2 courses

Active Learning

AiU was cautious about making too aggressive a move to active learning without enough experience to ensure good quality

<u>Their solution</u>

- Added a “lab” to Calculus 1 and 2, which they use as an active learning breakout session
- Reduced the number of students in breakout sections from 40 to 30 students
- Developed group-worthy tasks for the lab sessions
- Recently integrated clickers into lecture

GTA Professional Development

From "here is your book" to a substantial pd program

- Developed a three day beginning of the academic year workshop
- Goal to introduce student-centered approaches to teaching and present rationales for the effectiveness of this approach. Topics included ways to facilitate group work, lead whole class discussions, promote participation
- Adopted a Lead TA model in Calculus 1 and 2 (Ellis, 2015)
- Developed a 3 credit course for ongoing GTA professional development and support

Student Academic Supports
Math Learning Center (MLC)

A few characteristics of the MLC

- Development and management of the center has been organized almost entirely from within the department
- Directed by a tenured mathematics education professor from the mathematics department
- All TAs spend four of their office hours in the MLC each week, working with students from any P2C2 course
- Several faculty members hold their office hours in the MLC

How AiU Got Started

<u>Calculus Task Force</u>

- Charged with assessing the P2C2 program and determining how it might be revitalized within institutional constraints
- Looked into mathematics education research and brought in speakers for inspiration and guidance
- By design it included faculty with diverse interests and spheres of influence in the department
- Prepared proposals for consideration by the department, leading to open debate and discussion, and finally approval

Capitalized on Opportunities

- In 2012-2014 AiU received two small course redesign grants to support the use of ISAs, one in Precalculus and one in Calc 1
- The university adopted a new strategic plan, one of the explicit initiatives was to support student success – led to the new MLC
- Department chair served on a university wide task force to assess the impact of large classes. Result was a relatively low-cost change: Increase the number of GTAs and decrease the number of students they taught per week. One-time funds of $90,000 were allocated
- New wave of new faculty hired between 2014 and 2015 brought enthusiasm and energy to the department as well as new perspectives and experiences from other institutions

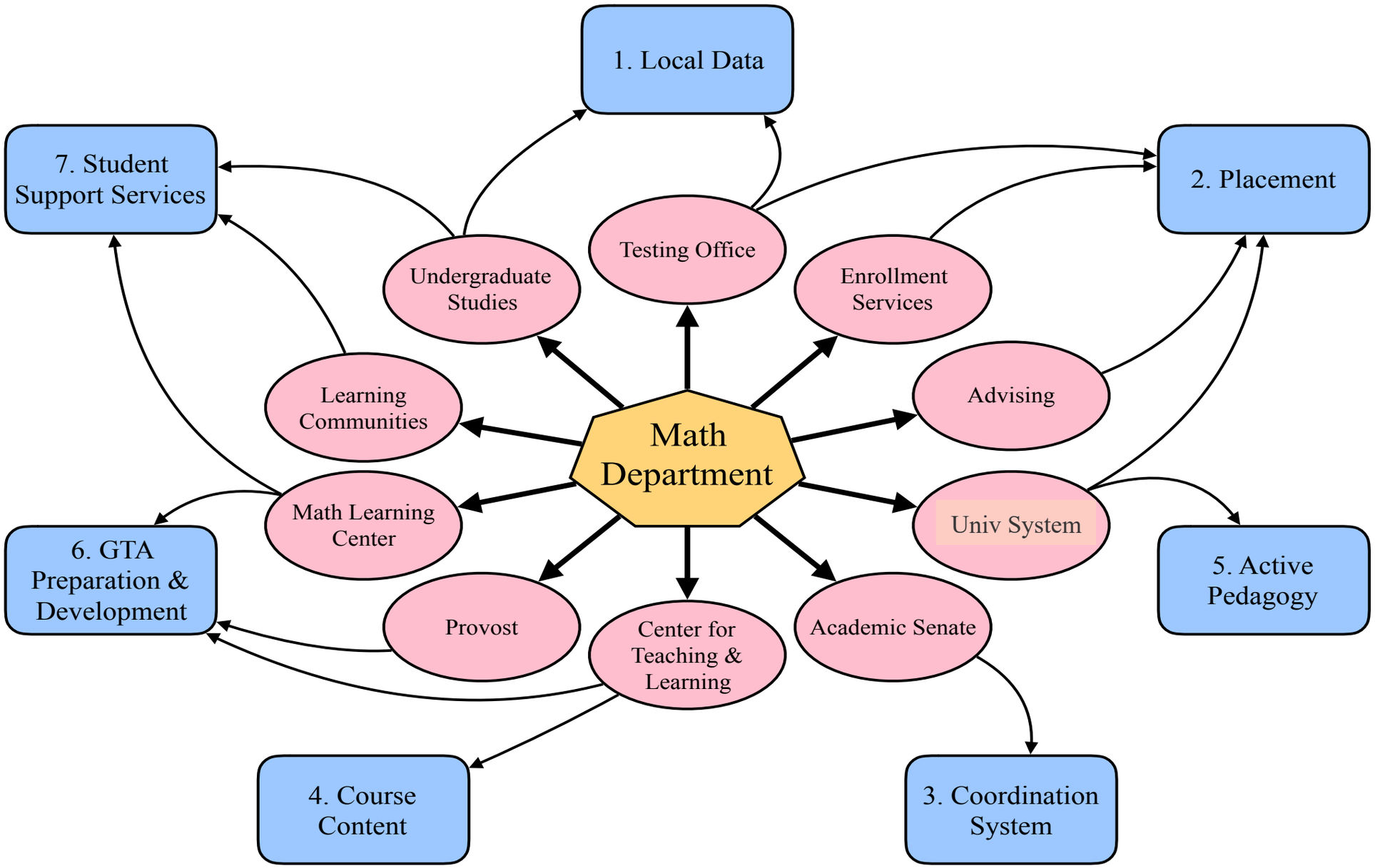
More Opportunities

Another crucial piece of the puzzle was a new chair who made the improvement of lower division mathematics instruction a priority

<u>Also benefited from outside partnerships</u>

- System wide chairs meetings led to increased cooperation with other institutions
- Several faculty participated in national meetings related to education (e.g., AMS Committee on Education, the Transforming Post-Secondary Education meetings, and conferences sponsored by the PtC research project)
- Participation in the Mathematics Teacher Education Partnership (MTE-P), which gave access to a networked community of educational researchers working to improve mathematics teaching across the K-16 level

Change agents at AiU worked holistically



AiU - Lessons Learned

- Single guiding principle – take a holistic approach
- Clear, transparent communication between department leadership, faculty, instructors, administrators, TAs is essential
- Involve the part-time and full-time lecturers
- Communicate regularly with administrators – this helped the initiative gain official support, which led to greater faculty buy-in
- Start thinking early on about how to schedule weekly or biweekly meetings – this can be surprisingly difficult
- Plan early for data collection and a plan for what data to collect and how it will allow you to be responsive to progress
- Put structures in place that make it harder to “undo” things

Lessons Learned: Reflections on all six case studies

Leadership

- Determined leaders and change agents
- Chair as active proponent
- Getting people involved
- Garnering Resources

Lessons Learned: Leadership

All innovation requires energy, stubbornness, dedication, and enough charisma to bring people along, so I wouldn't even worry much about curriculum. It's people. It's getting the people in place that want to make it happen, and they are going to put the energy into making it happen.

--Faculty member with former formal leadership role

Lessons Learned: Opportunistic Levers

- Leaders took advantage of opportunities
  - Friends in high places
  - Timely renovations
  - (Admin) interest in student retention/graduation
  - Institution initiatives or structural changes
- Politically savvy change agents
- “Never let a good crisis go to waste”

Lessons Learned: Flexibility

- Learn quickly from mistakes: Mistakes are inevitable with new initiatives; make them productive
- It's easier to fix change efforts than to initiate change efforts
- 90% better might be good enough

Lessons Learned: Coordination

- Focus on twin goals of
  - Building a community of practice
  - Fostering consistent and fair learning opportunities for students

- Effective course coordinators
  - Provide instructional resources while allowing for pedagogical autonomy
  - Bring instructors together to engage with problems of practice
  - Make instructors' lives easier
  - Function as a "choice architect"

Lessons Learned: Instruction

- Active Learning
  - Student engagement is critical
  - Mid-semester student evaluations for formative assessment can offset end of semester complaints
  - MAA Instructional Practices Guide (2018)
- Professional Development
  - Initial + ongoing
  - All instructors & TAs (including tutors)
- Staffing & hiring
- Infusing equitable and inclusive practices

Lessons Learned: Sustainability

- Be mindful of department culture, norms and power
  - Common vision (student success)
  - Communication, listening, collaboration
  - Negotiating the power of different groups
  - Use opportunities that you have, act on new ones
  - “See the system”
  - Manage fears
- Plan for change in personnel
- Put structures in place that make it hard to “undo” things
- Buy-in must extend “up” to administrators, deans, etc. to value student engagement in learning
- Professional development needs to be sustained over time, with explicit plans for enculturating new people

The End - Thank you!

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- PtC project website: maa.org/ptc
- SEMINAL project website: aplu.org/seminal

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