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# Transforming Precalculus Instruction: Evidence-Based Course Design

Wendy M. Smith

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# **Abstract for DBER Group Discussion on 2015-04-09**

**Presenter(s), Department(s):**

Wendy Smith

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University of Nebraska-Lincoln

**Title:**

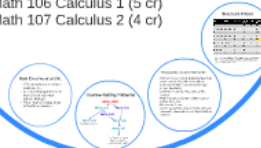
Transforming Precalculus Instruction: Evidence-Based Course Design

**Abstract:**

The UNL Mathematics Department has been focused on transforming precalculus instruction since 2012, with a goal of greater levels of student success. A short-term measure of student success is the passing rate (C or better), which has jumped from an average of 62% (2007-2011) to 80% for the past two falls. A longer-term measure of student success is recruiting and retaining undergraduates to STEM disciplines and careers. In this talk I will share specifics of the reform efforts (the who-what-when-where-why-and-how), and also share preliminary results from the research we have simultaneously been conducting into the reform efforts.

## Freshman Math Courses

- Math 100A Intermediate Algebra (3 cr)
- **Math 101 College Algebra (3 cr)**
- Math 102 Trigonometry (2 cr)
- Math 103 College Algebra and Trigonometry (5 cr = 101+102)
- Math 104 Business Calculus (4 cr)
- Math 106 Calculus 1 (5 cr)
- Math 107 Calculus 2 (4 cr)



## Next Steps

- Continue to collect data on course outcomes
- Begin to look at more longitudinal data (retention, course-taking patterns)
- Expand GTA training to LAs, tutors
- Expand efforts to Calculus
- Scale up efforts to other math depts in other universities (I-USE proposal to NSF is currently under review)



## Goals

### Initial Goals

- 75% success rates -- passing with a C or higher
- Success in calculus (106) at comparable levels from both students who enter from UNL precalculus courses and students who enter directly from high school

### Current Goals

- 80% success rates
- Improve student attitudes toward mathematics
- Success in calculus (106) at comparable levels from both students who enter UNL precalculus courses and students who enter directly from high school



# Transforming Precalculus Instruction: Evidenced Based Course Design

Wendy M. Smith  
Center for Science, Mathematics  
and Computer Education  
Presentation to the DBER Seminar,  
April 9, 2015



## Support & Connections

- The project has had support from the Math Dept throughout
- Early support by SVCAA (Brace renovations, .25 GTA one semester)
- Grant from Association of Public and Land-grant Universities (APLU)
- MAA grant to fund learning assistants
- Mathematics Teacher Education Partnership: one focus is *active learning mathematics*
- Ongoing collaboration with UNO, U of Colorado Boulder, Auburn, U of West Virginia

## Data Collection

- Instructor survey & interviews
- Student attitude survey pre/post
- Student exam & course grades
- Student focus group interviews
- Interviews of involved faculty
- Analyze exams
- Observations (RTOP)
- Document GTA training & teaching seminar
- Document institutional change (efforts)

### Class Coordinator

- Goals:
  - Make a self-reflection
  - Make a list of students who are struggling
  - Make a list of students who are successful
  - Make a list of students who are struggling
  - Make a list of students who are successful

### Learning Assistants

- Goals:
  - Support group work & students who are struggling
  - Make a list of students who are struggling
  - Make a list of students who are successful
  - Make a list of students who are struggling
  - Make a list of students who are successful

### Graduate Teaching Assistant Training

- Goals:
  - Teach a list of students who are struggling
  - Make a list of students who are struggling
  - Make a list of students who are successful
  - Make a list of students who are struggling
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## Active Learning Mathematics

### Goals:

- Teaching methods & classroom norms: engage students in sense-making activities
- Students develop habits of mind of mathematical thinkers: solve problems, conjecture, experiment, explore, create, communicate reasoning

### Strategies:

- Cooperative learning (group work)
- In-class worksheets to direct focus of group work to meet math objectives
- Team quizzes



### Learning Environment

- Goals:
  - Make a list of students who are struggling
  - Make a list of students who are successful
  - Make a list of students who are struggling
  - Make a list of students who are successful

### First Year Mathematics Task Force

- Goals:
  - Make a list of students who are struggling
  - Make a list of students who are successful
  - Make a list of students who are struggling
  - Make a list of students who are successful

### Early Formative Assessment

- Goals:
  - Make a list of students who are struggling
  - Make a list of students who are successful
  - Make a list of students who are struggling
  - Make a list of students who are successful



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## ***Initial Goals***

- 75% success rate
- Success in calculus from both student precalculus course directly from high

## ***Current Goals***

- 80% success rate
- Improve student
- Success in calculus from both student courses and student school

## **Data**

- Instructor
- Student at
- Student ex
- Student fo
- Interviews
- Analyze e
- Observati

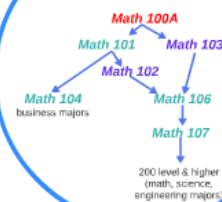
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## Math Enrollment at UNL

- 67% of freshman enroll in a math course
- No other dept garners more than 33% of freshmen (Music, Biology)
- Thus, Math is a huge factor in freshman retention

## Course-Taking Patterns



## Success Rates

Course	Term	Enrollment	Success Rate	Success Rate	Success Rate
Math 100A	Fall 2010	450	75.0%	75.0%	75.0%
Math 100A	Spring 2011	450	75.0%	75.0%	75.0%
Math 100A	Fall 2011	450	75.0%	75.0%	75.0%
Math 100A	Spring 2012	450	75.0%	75.0%	75.0%
Math 100A	Fall 2012	450	75.0%	75.0%	75.0%
Math 100A	Spring 2013	450	75.0%	75.0%	75.0%
Math 100A	Fall 2013	450	75.0%	75.0%	75.0%
Math 100A	Spring 2014	450	75.0%	75.0%	75.0%
Math 100A	Fall 2014	450	75.0%	75.0%	75.0%
Math 100A	Spring 2015	450	75.0%	75.0%	75.0%

Note: College Algebra & Trig. spring enrollment tends to be ~75 students as success rate is extremely variable and thus not shown here.

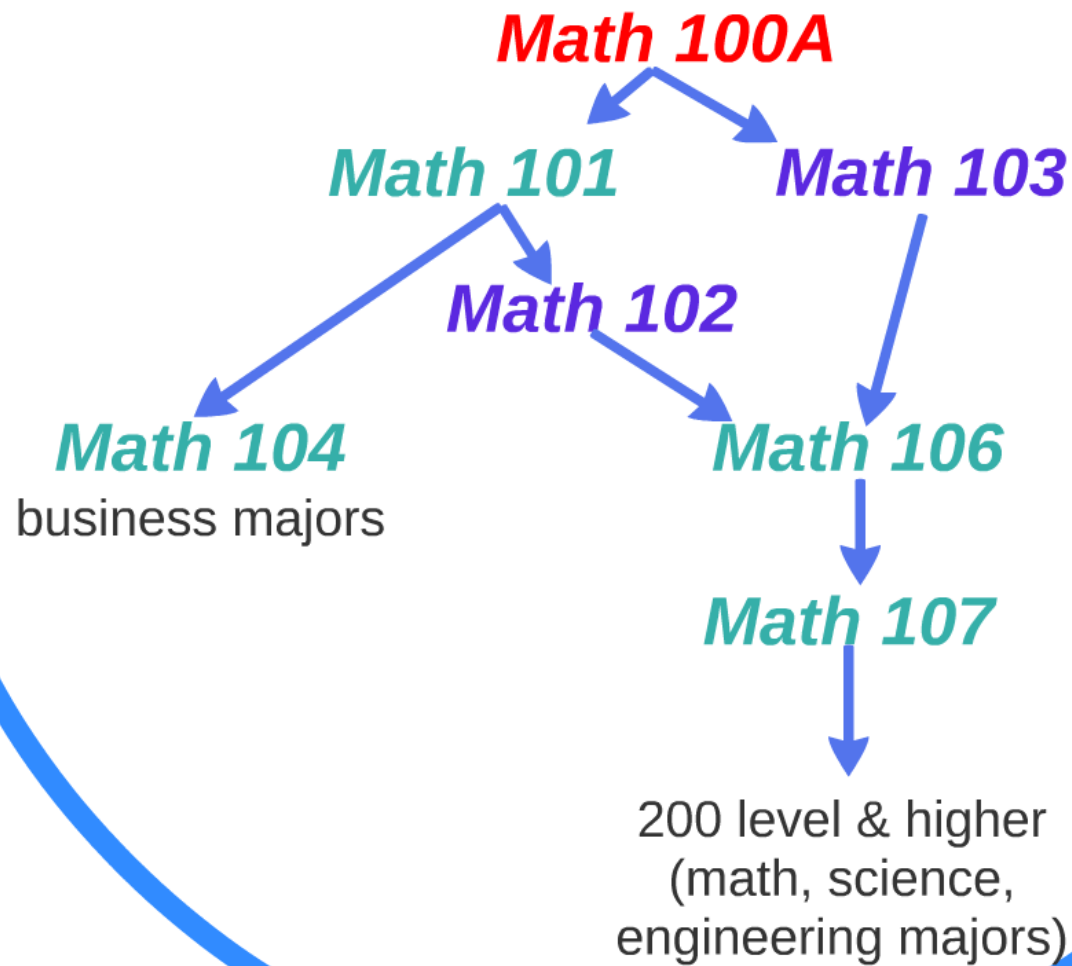
## Precalculus Course Structure

- Instructors are mostly graduate teaching assistants (GTAs) with a few adjunct instructors (often former/current high school teachers)
- Common Exams (unit exams & final exams)
- Math Resource Center: a tutoring room staffed by GTAs
- Placement Exam
- Covering algebra, trigonometry, pre-calc concepts, place into one of the freshman courses

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# Success Rates

Course	Term	Enrollment	First-Time Freshmen	Sections	Success Rate
College Algebra	Fall 2011	850	70.8%	29	64%
College Algebra	Spring 2012	560	1.4%	17	55%
College Algebra	Fall 2012	686	70.2%	25	59%
College Algebra	Spring 2013	458	3.9%	15	73%
College Algebra	Fall 2013	721	72.5%	26	81%
College Algebra	Spring 2014	407	2.7%	14	71%
Coll Alg & Trig	Fall 2011	260	76.7%	9	68%
Coll Alg & Trig	Fall 2012	277	85.6%	9	72%
Coll Alg & Trig	Fall 2013	280	81.7%	9	76%

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# Goals

## *Initial Goals*

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## *Lessons Learned*

- Students need an incentive to complete pre/post surveys (complete during class; give quiz points)

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## Learning Assistants

Support group work & student engagement  
 Goals:  
 • Support undergraduates to assist in course instruction  
 • Recruit from majors, "A" students  
 • Support larger class sizes



## Learning Environment

Support group work easy and accessible for students  
 Goals:  
 • Classroom tables/chairs for group work  
 • Classroom whiteboard, document camera  
 • Dedicated time  
 • Math 101: 150 to 225 min/wk  
 • Math 103: 250 to 300 min/wk



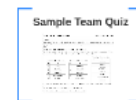
# Active Learning Mathematics

## Goals:

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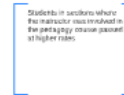
## Strategies:

- Cooperative learning (group work)
- In-class worksheets to direct focus of group work to meet math objectives
- Team quizzes



## Graduate Teaching Assistant Training

Goals:  
 • Teach GTAs elements of effective instruction  
 • Gain buy-in for Active Learning philosophy  
 Strategies:  
 • Pre-semester training workshop  
 • Year-long course for first-time GTAs  
 • Mentoring



## First Year Mathematics Task Force

Goals:  
 • Faculty support for high-quality GTA instruction  
 • Maintain high standards for learning  
 Strategies:  
 • Faculty mentor GTAs  
 • Faculty review syllabi & exams for rigor, content, goals

# Sample Worksheet

## Worksheet 2.1: Input and Output

Math 101 Spring 2015

**Problem 1** (Warm-up). Let  $C(x) = 0.08x + 7.50$  be the cost of a road trip in dollars, where  $x$  is the number of miles you travel. Give a possible interpretation for the slope and  $y$ -intercept.

**Problem 2** (Warm-up, §2.1, #2). If  $g(x) = x^2 - 5x + 6$ , find  $g(0)$  and solve  $g(x) = 0$ .

**Problem 3** (Ex. 1). Let  $f(t)$  be the total number of reported flu cases at UNL by the  $t$ th day of the semester. Answer the following with complete sentences.

What does  $f(103)$  mean?

What does  $f(50)$  mean?

What does  $f(15) = 73$  mean?

# Sample Team Quiz

Team Quiz 1: January 28, 2015

Math 101 Spring 2015

Names: \_\_\_\_\_

Directions: You may work with the people at your table, but you must turn in team quizzes in groups of two or three. You may not use your notes, worksheets, or other resources on this team quiz.

**Be sure to show work and/or explain your reasoning.**

**Problem 1.** The following tables represent the relationship between the button number,  $N$ , that you push, and the snack,  $S$ , delivered by three different vending machines.

**Vending Machine #1**

$N$	$S$
1	M&Ms
2	pretzels
3	dried fruit
4	Hersheys
5	fat-free cookies
6	Snickers

**Vending Machine #2**

$N$	$S$
1	M&Ms or dried fruit
2	pretzels or Hersheys
3	Snickers or fat-free cookies

**Vending Machine #3**

$N$	$S$
1	M&Ms
2	M&Ms
3	pretzels
4	dried fruit
5	Hersheys
6	Hersheys
7	fat-free cookies
8	Snickers
9	Snickers

- a) To have a useful vending machine, must  $S$  be a function of  $N$  or  $N$  a function of  $S$ ? Explain.
- b) For which vending machine(s) is  $S$  a function of  $N$ ?
- c) For which vending machine(s) is  $N$  not a function of  $S$ ?

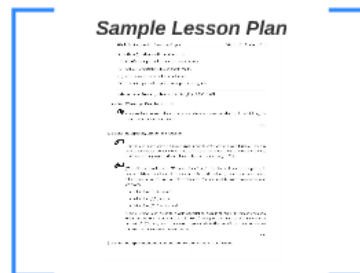
# Close Coordination

## Goals:

- Build out effective practices
- Have GTAs focus on students, not material

## Strategies:

- Director of First Year Mathematics Programs Assistant conveners
- Common lesson plans
- Common exams
- Weekly coordination meetings





# Sample Lesson Plan

Week 3: Section 2.1 *Input and Output*

Math 101 Spring 2015

**Objectives (Students will be able to...):**

- (i) identify the input and output of a given function,
- (ii) evaluate a function to find an output value,
- (iii) solve an equation to find an input value,
- (iv) interpret input and output pairs as points on a graph.

**Relevant exercises & problems:** 3,8,13-14,16b,18,20-22,29-31

[5 mins] **Warm-up: Exercise 2, p. 72**



Allow students to work alone or in groups. Go over answers on the board, highlighting the input/output pairs in each part.

0:05

[15 mins] **Interpreting Inputs and Outputs**



This problem incorporates a function given in words that does not have a formula. You may want to remind your students that this is still a valid function, and you will certainly want to model correct language for them. (That is, both write and say  $y = f(t)$ .)



(The following problem is on Worksheet 2.1.) Let  $f(t)$  be the total number of reported flu cases at UNL by the  $t$ th day of the semester. Discuss the following questions with your class, asking them to explain with complete sentences. You may want to write these sentences on the board.

- What does  $f(103)$  mean?
- What does  $f(50)$  mean?
- What does  $f(15) = 73$  mean?

Some questions to ask students in your discussion include: Is  $f(103)$  a function or a number? What does  $f(15) = 73$  mean on a graph? Would we expect this function to be increasing or decreasing? (You may want to mention to your students that we will ask them to interpret functions in complete sentences on exams.)

0:20

[10 mins] **Interpreting inputs and outputs for a function with a formula**

# Graduate Teaching Assistant Training

## Goals:

- Teach GTAs elements of effective instruction
- Gain buy-in for Active Learning philosophy

## Strategies:

- Pre-semester training workshop
- Year-long course for first-time GTAs
- Mentoring

Students in sections where the instructor was involved in the pedagogy course passed at higher rates

Math 101 Student Pass Rates by Instructor Involvement in Pedagogy Course

	In Pedagogy Course	Not in Pedagogy Course	Total
Passed	209	127	426
Failed	64	43	107
Total	363	170	533
Pass Rate	82%	75%	

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Math 101 Student Pass Rates  
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oup

sheet

Task 10: Area 2015  
2016-2017  
2018-2019  
2020-2021  
2022-2023

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## Goals:

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- Maintain high standards for learning

## Strategies:

- Faculty mentor GTAs
- Faculty review syllabi & exams for rigor, content, goals

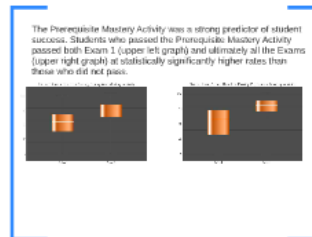
# Early Formative Assessment

## Goals:

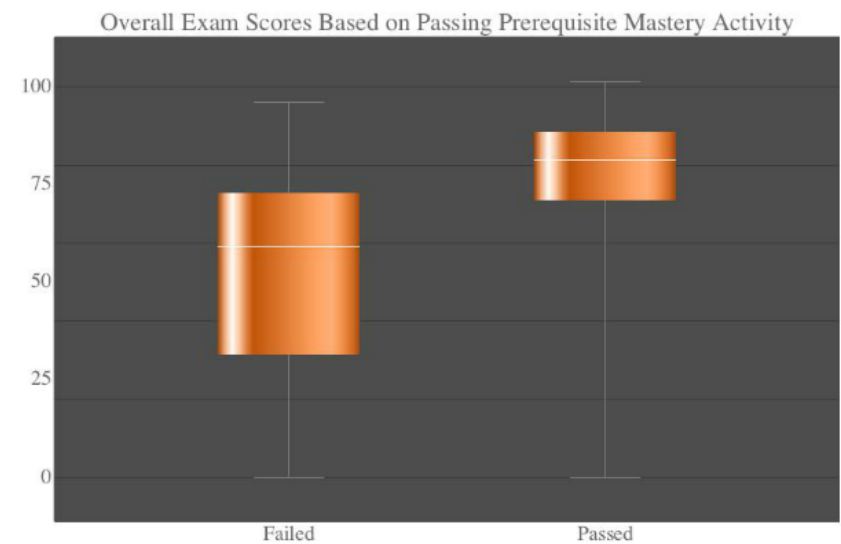
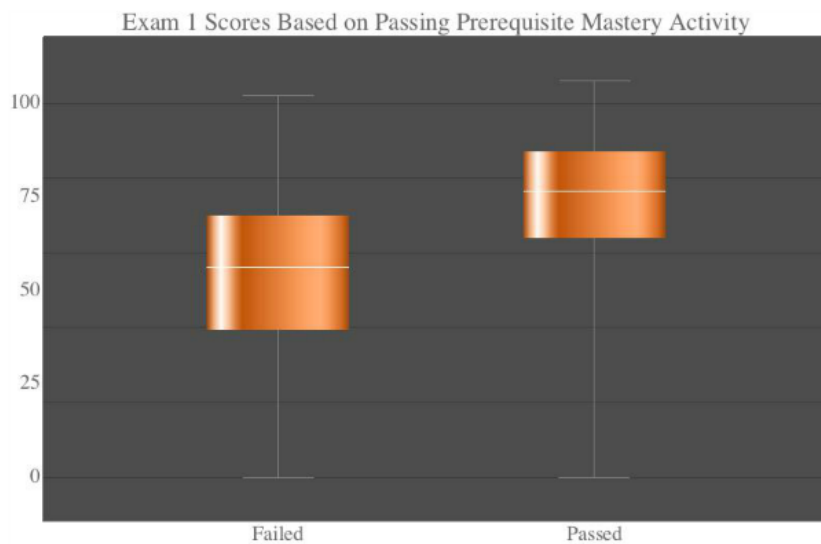
- Engage students at start of course
- Provide students opportunity to demonstrate mastery of prerequisite knowledge

## Strategies:

- Prerequisite Mastery Activity- material a “B” high school Algebra 2 student would know & be able to do



The Prerequisite Mastery Activity was a strong predictor of student success. Students who passed the Prerequisite Mastery Activity passed both Exam 1 (upper left graph) and ultimately all the Exams (upper right graph) at statistically significantly higher rates than those who did not pass.



# Learning Environment

## Goal:

- Make group work easy and natural for students

## Strategies:

- Classroom tables/chairs for group work
- Classroom whiteboard, document camera
- Extended time
  - Math 101: 150 to 225 min/wk
  - Math 103: 250 to 300 min/wk

"I love my group." "We're teaching our groups, like to the people who don't understand it."  
-Math 103 students



"We run into problems that individually we would probably get stuck on, but instead of working it out of the books ourselves or trying to get lined up with the professor, we can group together and try and get it done. We've even gone as far as get together to get the homework done and branching out into other problems and not just the team quiz."  
-Math 101 Student

Students in sections held in Braze labs (renovated rooms) passed at higher rates than sections in other rooms.

Math 101: Section Pass Rates				
Section	Students	Passes	Rate	Rate
101-1	45	35	78%	85%
101-2	45	35	78%	85%
101-3	45	35	78%	85%
101-4	45	35	78%	85%
101-5	45	35	78%	85%



*“I love my group” “We’re teaching our groups, like to the people who don’t understand it.”*

–Math 103 students





*“We run into problems that individually we would probably get stuck on, but instead of working it out of the books ourselves or trying to get lined up with the professor, we can group together and try and get it done. We’ve even gone as far as get together to get the homework done and branching out into other problems and not just the team quiz.”*

*-Math 101 Student*

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Math 101 Student Pass Rates  
by Classroom Location

	In Brace Labs	Not In Brace Labs	Total
Passed	416	39	455
Failed	98	13	111
Total	514	52	566
Pass Rate	81%	75%	

# Learning Assistants

Goal:

- Support group work & student engagement

Strategies:

- Hire undergraduates to assist with course instruction
- Recruit from majors, “A” students
- Can support larger class sizes

Students in sections with a Learning Assistant passed at higher rates than sections without a learning assistant.

Math 101 Student Pass Rates by LA Use			
	LA	No LA	Total
Passed	55	120	45
Failed	25	85	110
Total	80	205	285
Pass Rate	68%	58%	

Students in sections with a Learning Assistant passed at higher rates than sections without a learning assistant.

Math 101 Student  
Pass Rates by LA Use

	LA	No LA	Total
Passed	335	120	455
Failed	76	35	111
Total	411	155	566
Pass Rate	82%	77%	

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**Questions?**

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***Questions?***