

Active Collaborative Learning and Faculty Development in the Redesign of Introductory Mathematics Course

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Why is Our Redesign Important?

- ▶ Introductory courses enroll twice as many students as all other mathematics courses combined [CBMS, 2000].
- ▶ Intro math courses have the greatest impact on strengthening students' quantitative and logical reasoning abilities [CUPM, 2004].
- ▶ What are difficulties in Intro Math Courses?
 - ▶ Low proficiency in symbol manipulation
 - ▶ Perception that mathematics eludes mastery
 - ▶ Lack of engagement and effective practice

[Levi et al, 2016]

IU Northwest – regional, urban, commuter university with 40% minority student population

- Redesign Courses – Gateway courses (20-40 students)

M100 Mathematics for Liberal Arts and Nursing – 9-11 sections per semester

two interventions in 2016 and two in 2017 (instructors volunteered),

FA2018 – all 9 sections

M117 Intermediate Algebra – 5 sections,
2 with interventions (two of the authors)

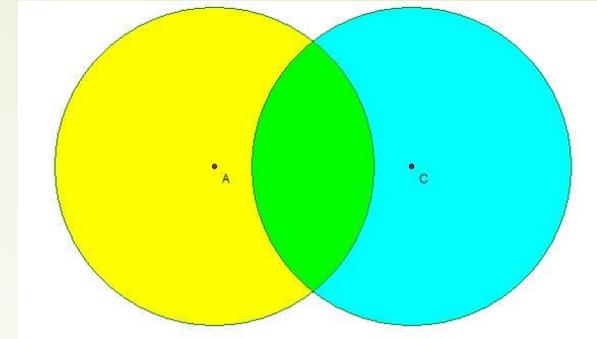


Our Multifaceted Approach

- ▶ **PIGS** - Study Active Collaborative Learning
- ▶ Pursue Grant Writing – Provide Resources for Faculty Development and Involvement in Course Redesign
 - ▶ Mathematics Placement Peer Coaching
 - ▶ Carefully Calibrated Placement Exams
 - ▶ Explore meaningful problems in groups, test conjectures, find solutions, and explain results.
 - ▶ Common Midterm and Final Exams
 - ▶ Attendance and Homework
 - ▶ Associate Faculty Workshop



Definition of Active Collaborative Learning

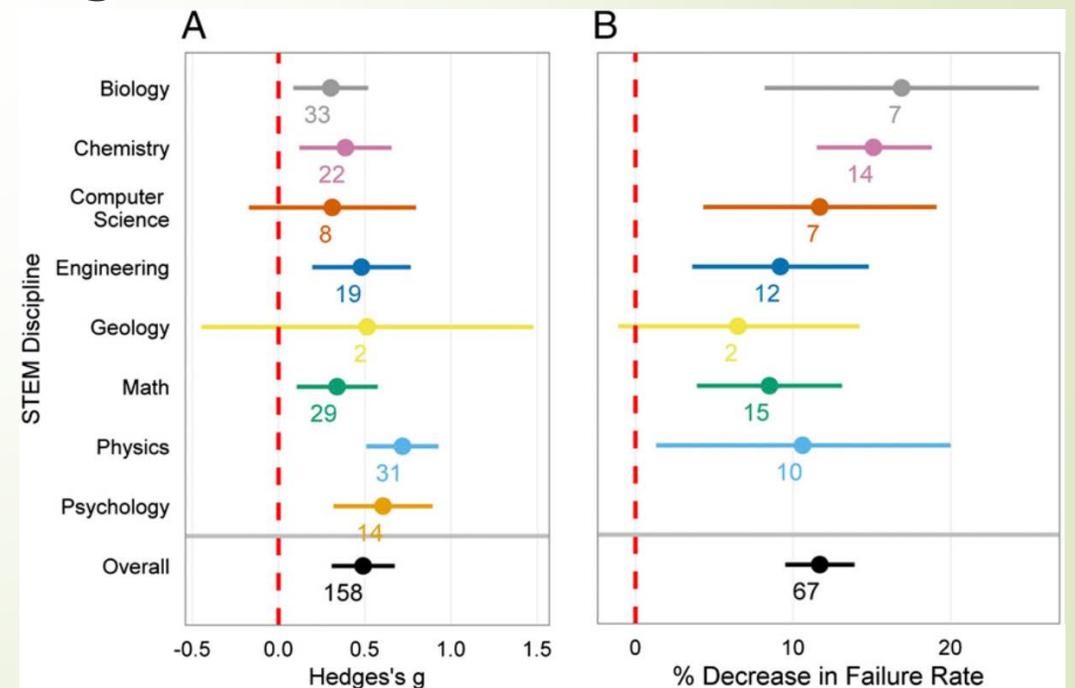


- Instructional method that engages students in the learning process
 - activities introduced into the classroom with varying intensities (10% to 100% of class time)
- Requires students to do meaningful learning activities and think about what they are doing
- Instructor provides formative assessment
- Inquiry-based learning (IBL) – closely related – emphasizes individual knowledge construction supported by peer interactions: exploring, testing conjectures, developing proofs and solutions, explaining

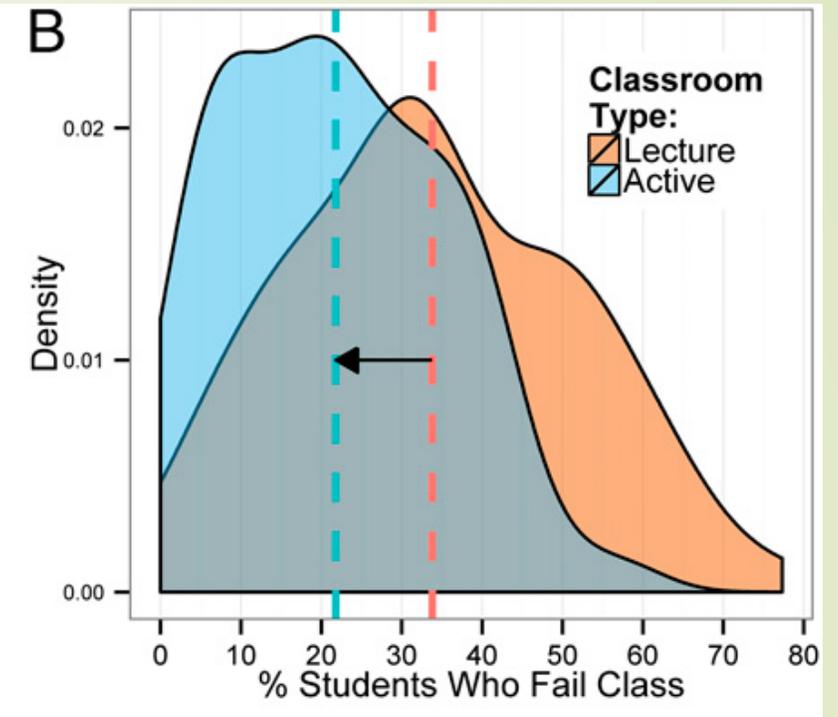
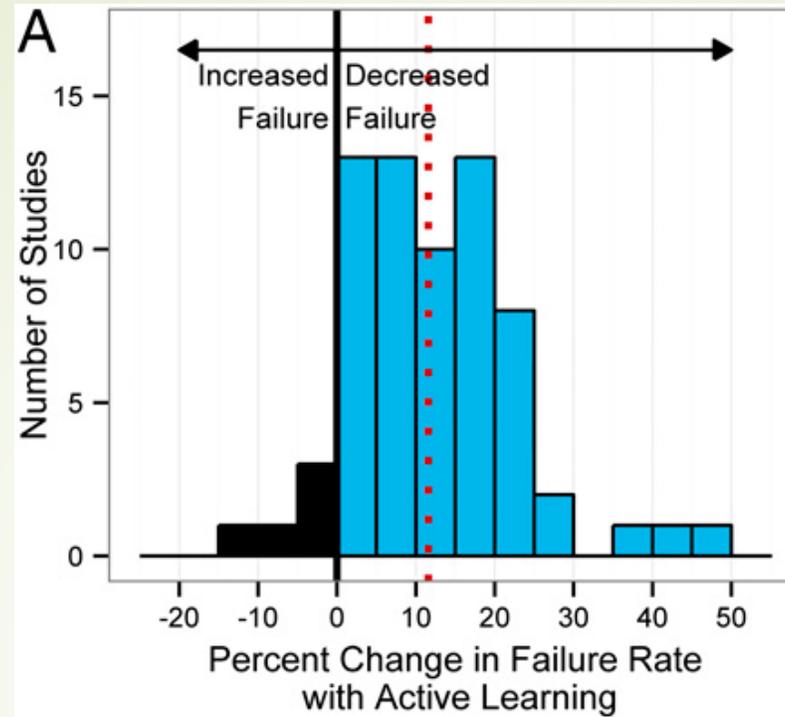
Active learning increases student performance in science, engineering, and mathematics

[Freeman et al, 2014]

- ▶ Meta-analysis of 225 studies
- ▶ Examination scores or failure rates when comparing student performance in undergraduate STEM courses under Traditional Lecturing versus Active Learning.

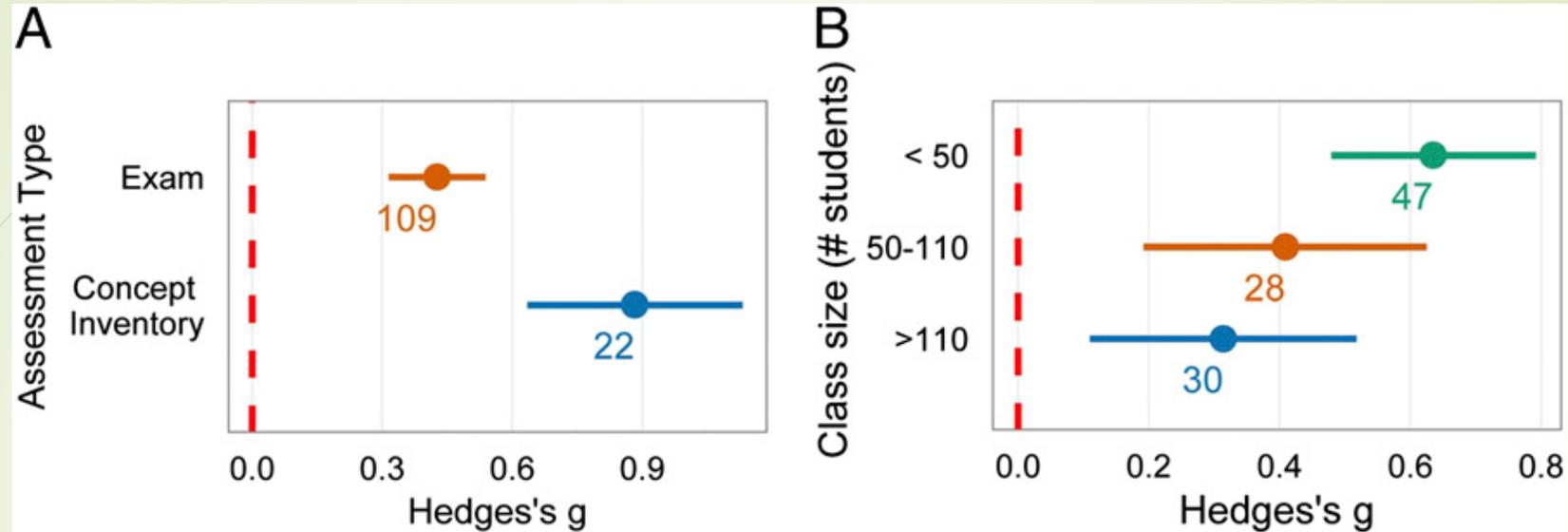


Results



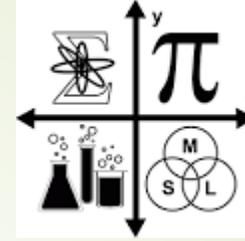
- Average examination scores improved by about 6% in active learning sections
- Students in classes with traditional lecturing were 1.5 times more likely to fail than were students in classes with active learning.
- Heterogeneity analyses indicated that both results hold across the STEM disciplines

Further Findings



- Active learning increases scores on concept inventories more than on course examinations
- Active learning has a greater impact on student mastery of higher- versus lower-level cognitive skills [Haukoos GD, Penick JE (1983), Martin et al (2007), Cordray et al (2009), Jensen JL, Lawson A (2011)]
- Active learning appears effective across all class sizes—although the greatest effects are in small ($n \leq 50$) classes.

More Results



- ▶ No statistically significant difference in active learning's effect size when comparing
 - ▶ (i) courses for majors versus non-majors ($Q = 0.045$, $df = 1$, $P = 0.883$; Table S1D), or
 - ▶ (ii) introductory versus upper-division courses ($Q = 0.046$, $df = 1$, $P = 0.829$; Tables S1E and S2D).
- ▶ Active learning has a disproportionately beneficial effect on members of minority groups in STEM fields [Uri Treisman (2009)]

Introduction to Mathematical Modeling [Levi et al, 2016]

- Majors: education, social and health sciences, arts and humanities
- Up to 40 students in class
- Objective: translate everyday problems into mathematics language, use math and technology to solve them, communicate solution
- Hybrid of different instructional techniques over 4 semesters: face-to-face, online, partially or fully in computer lab; Excel worksheets, homework, Quizzes, Exams in CMS (increasing number of interventions from SP11-FA12)

Exercise 16, Section 2.4. Monthly Payment on a Loan (the numerical values are different from the print version in the book).

If you borrow \$6,700 at an APR of r (as a decimal) from a lending institution that compounds interest continuously, and if you wish to pay off the note in 4 years, then your monthly payment M , in dollars, can be calculated using the formula $M = 6700(e^{r/12} - 1)/(1 - e^{-4r})$. Your budget will allow a payment of \$165 per month, and you are shopping for an interest rate that will give a payment of this size. What interest rate do you need to find? (Round your answer to two decimal places.)

Solution. We need to solve the following equation for r : $165 = 6700(e^{r/12} - 1)/(1 - e^{-4r})$. We start by setting up a table of values for r and M . Since a lending institution always charges a non-zero rate (and since our formula is not defined when $r = 0$), we start with $r = 0.01$ corresponding to the interest rate of 1%. We autofill to $r = 0.1$ (or 10%). We enter M in the yellow cell B18 as $=6700*(EXP(A18/12)-1)/(1-EXP(-4*A18))$.

| r | M |
|----------|----------|
| 0.01 | \$142.45 |
| 0.02 | \$145.36 |
| 0.03 | \$148.31 |
| 0.04 | \$151.30 |
| 0.05 | \$154.33 |
| 0.06 | \$157.40 |
| 0.07 | \$160.50 |
| 0.084249 | \$165.00 |
| 0.09 | \$166.84 |
| 0.1 | \$170.06 |

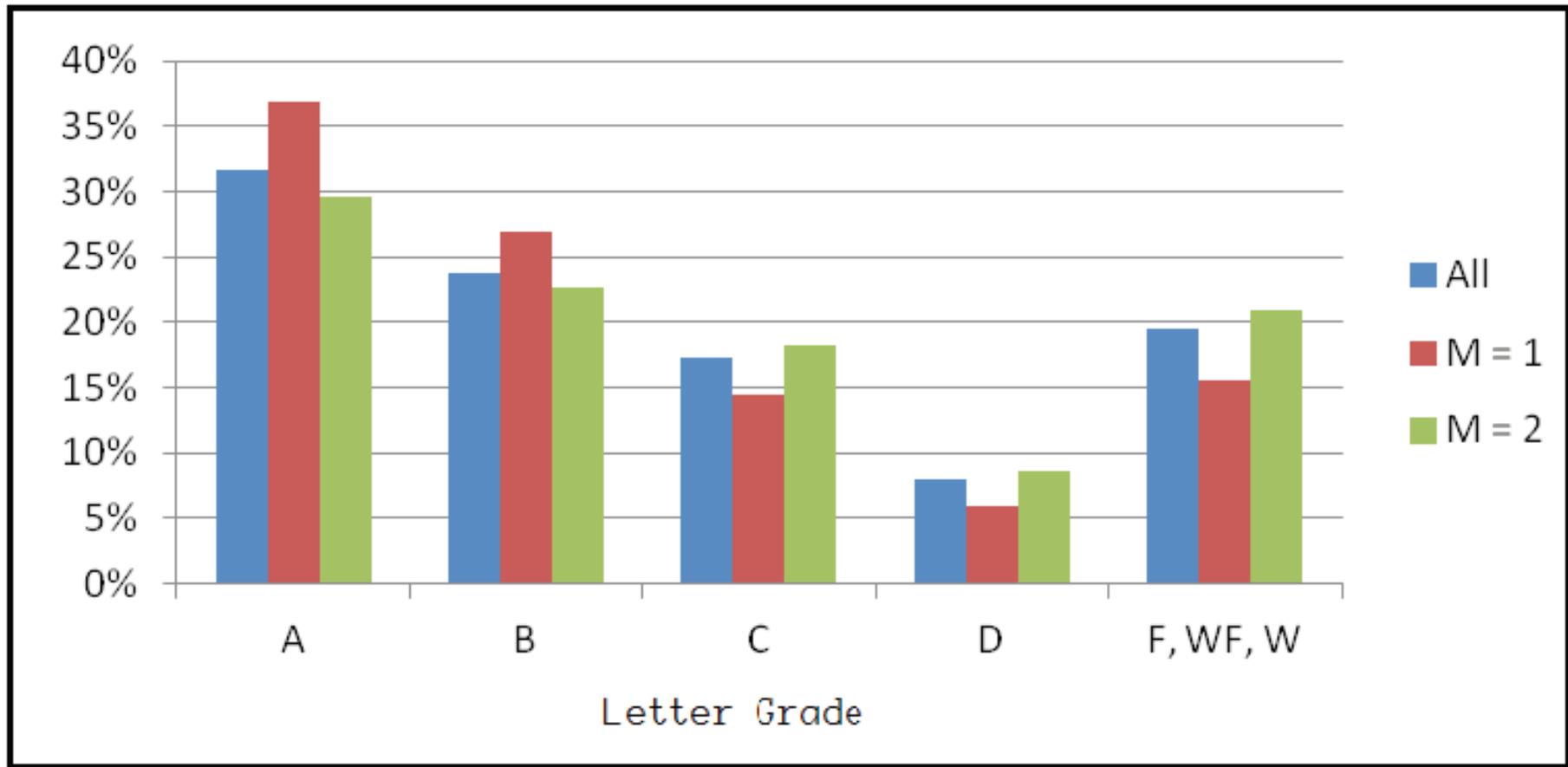
The closest value to 165 in column B is 163.50 in the green cell B25. We use Data-> What-If Analysis -> Goal Seek to set cell B25 to 165 by changing the cell A25.

| | | |
|----|----------|----------|
| 20 | 0.05 | \$148.31 |
| 21 | 0.06 | \$151.30 |
| 22 | 0.07 | \$154.33 |
| 23 | 0.08 | \$157.40 |
| 24 | 0.09 | \$160.50 |
| 25 | 0.084249 | \$165.00 |
| 26 | 0.09 | \$166.84 |
| 27 | 0.1 | \$170.06 |



From the table above $r = 0.0842$ (blue cell), or in percentage points $r = 8.42\%$.

- Communication.
- In-class Assignments and Active Learning - a graded assignment during each class period



Grades in all sections of Mathematics Modeling Class, Spring 2010-Fall 2012. M=1 : Intervention classes, M=2 : All others [Levi et al, 2016]

Revision of the M100 class at IU Northwest

- Mathematics Placement Peer Coaching
- Carefully Calibrated Placement Exams



Active Collaborative Learning

In each intervention section, the instructor volunteered to incorporate five collaborative activities into their lectures. Each activity

- covers one topic/concept in the course
- is designed as an application problem
- takes about 15 - 20 minutes
- is completed by a small group of students (3 - 4)



Sample problems

Imagine that last summer you and your friends decided to run a kayak-rental business on Lake Michigan. Because the income is good, you are continuing the kayak-rental business until the kayak season is over. Let's assume that when you started your business, you charged \$12 per canoe and averaged 36 rentals a day. You read in *Canoe & Kayak Magazine* that, for every fifty-cent increase in rental price, the average business can expect to lose two rentals a day. Use this information to maximize your income. Should you change your rental charge based on the information obtained?



You are playing the Pokemon go in Chicago. The number of Pokemon you might see is inversely proportional to the distance between your location and downtown Chicago. Suppose that you capture 4 Pokemon when you are 3000 meters away from downtown Chicago. How many Pokemon do you expect to capture when you are 500 meters away from downtown Chicago?

Cancer Treatment Protocol

The design of the treatment protocol for cancer patients is very important. An incorrect calculation of a rate for cancer drug, fluorouracil, lead to a complete organ failure of a 43-year-old cancer patient that was being treated in an ambulatory clinic in July 2006.

The following is the actual problem the medical staff faced. Would you be able to determine the rate correctly?

A doctor ordered Fluorouracil (cancer medicine) at rate of 5,250 mg intravenous (IV) continuous over 4 days. The fluorouracil bag contained solution with concentration of 45.57 mg/mL. Determine the infusion rate of IV for the patient. That is, at what rate (mL/hour) the patient should receive 5,250 mg fluorouracil over 4 days?



COUNTING TECHNIQUES

Harry Potter's closet contains 12 numbered brooms, of which 8 are Comet Two Sixty's (numbered 1 - 8) and 4 are Nimbus Two Thousand's (Numbered 9-12). Harry, Ron, George and Fred want to sneak out for a game of Quidditch in the middle of the night. They don't want to turn on the light in case Snape catches them. They reach in the closet and pull out a sample of 4 brooms. How many different ways can Harry and his friends choose their brooms? Identify two possible solutions here: one is if we only care about which four brooms are pulled out, the other is if we keep track of which broom Harry gets, which broom Ron gets, and so on. Explain why the answers are different for these two scenarios.





Experience of Collaborative Learning in Class

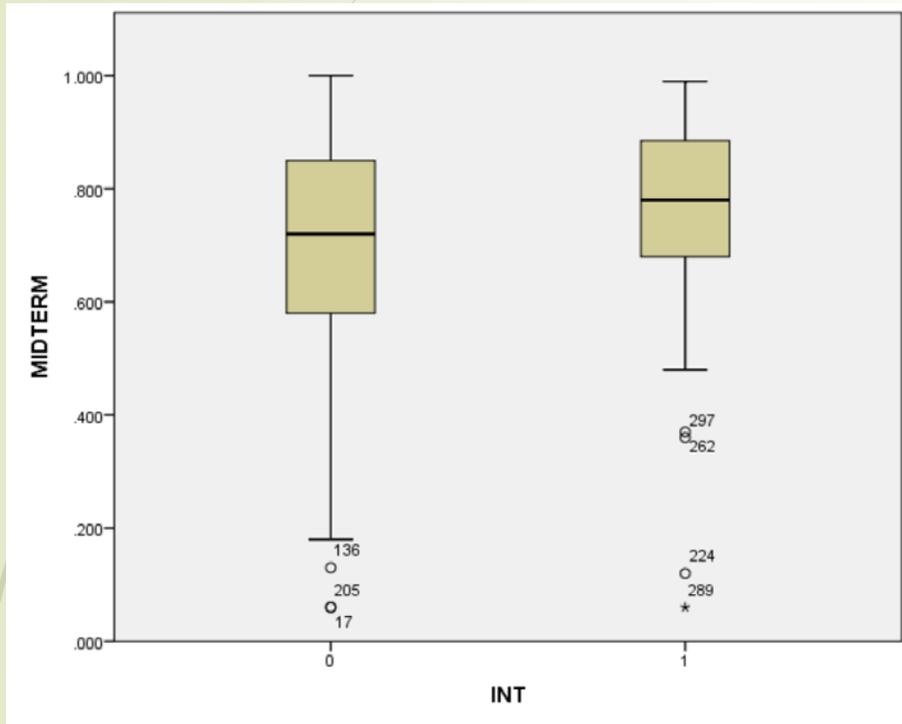
- ▶ Encourage students to spend a little time to introduce themselves to each other and (maybe) leave school contact info for study group outside classes
- ▶ Most students like the opportunities to discuss with their classmates and solve problems together as a group
- ▶ Students agree collaborative activities make them do more critical thinking
- ▶ Some students were reluctant to join the group discussion at the beginning of the semester; instructors may need to intervene when this happens
- ▶ Time management will be a challenge for instructors who conduct activities the first time in his/her class



Faculty development

- ▶ **IU Regional Campuses Teaching and Learning Prototype Grant** helped fund a workshop for all faculty teaching the course including associate faculty
- ▶ Associate faculty received stipends
- ▶ Anonymous Survey
 - ▶ feedback about success, too much or too little time, difficulty for your students, appropriateness of the problem, or any other feedback for each of the activities that instructors used with their students

M100 2016 Common Midterm and Final Exams Results

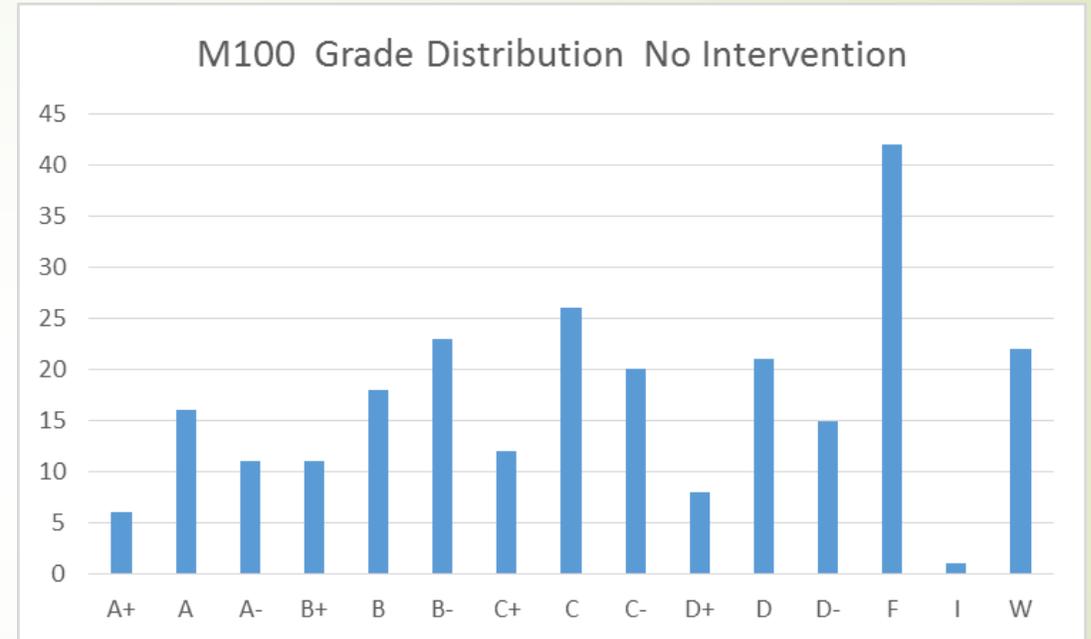
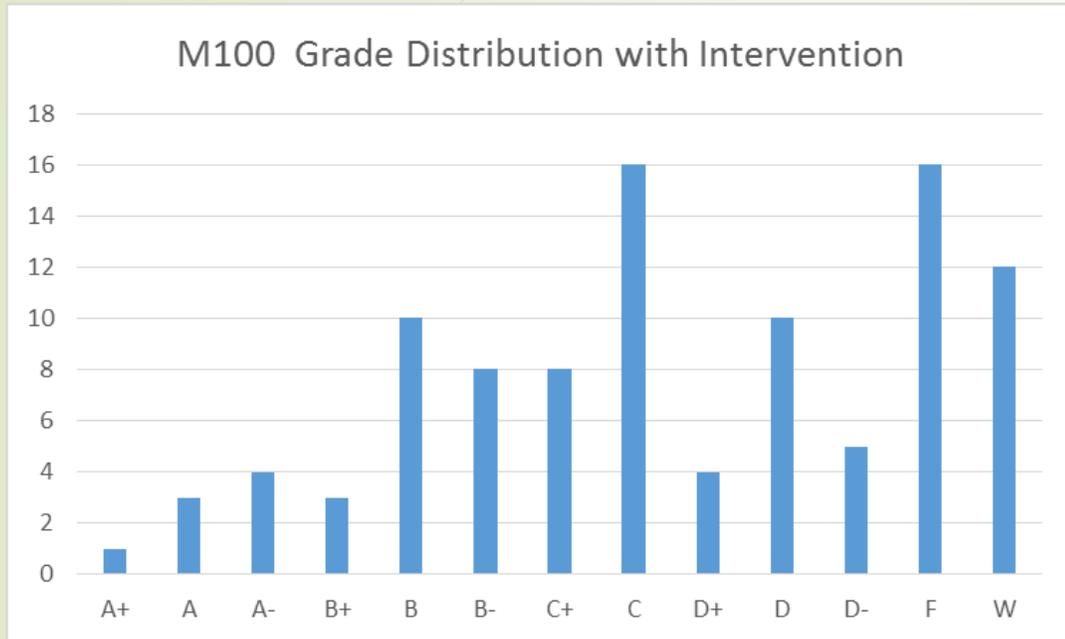


| M100 | INT | N | Mean | Std. Deviation |
|---|-----|-----|-------|----------------|
| MIDTERM | 0 | 219 | 0.701 | 0.193 |
| | 1 | 84 | 0.758 | 0.180 |
| t-test for Equality of Means $p = 0.021$ (2-tailed) EVA | | | | |



| M100 | INT | N | Mean | Std. Deviation |
|---|-----|-----|-------|----------------|
| FINAL | 1 | 83 | 0.608 | 0.185 |
| | 0 | 188 | 0.639 | 0.174 |
| t-test for Equality of Means $p = 0.181$ (2-tailed) EVA | | | | |

M100 2016 Grade Distributions



DFW rates

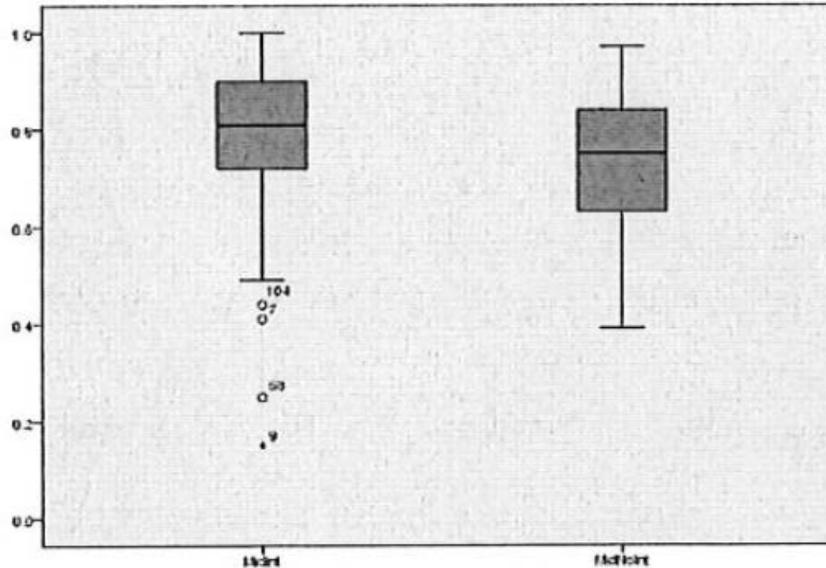
0. 470 intervention classes

0. 433 no intervention classes

M100 FA 2017

Intervention Results

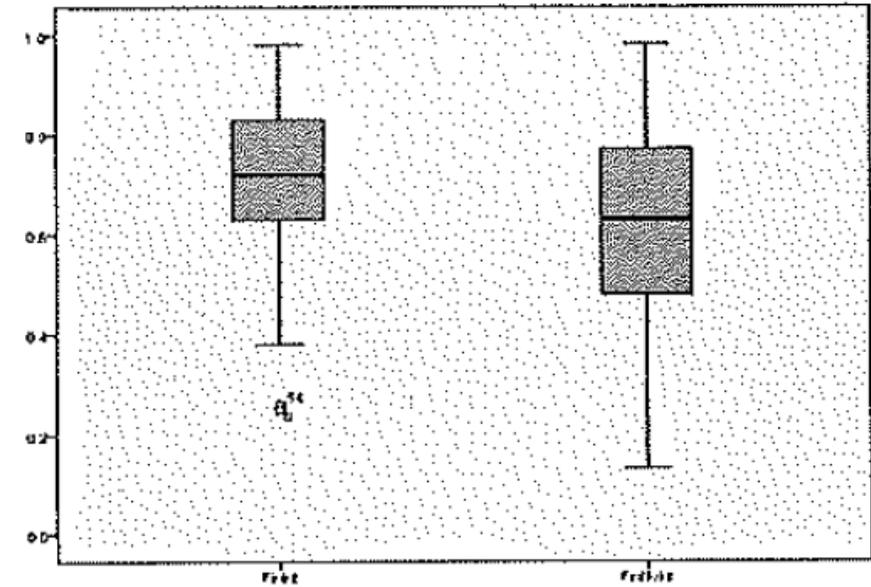
M100 Midterm Exam



| INT | N | Mean | Std. Dev |
|-----|-----|--------|----------|
| 0 | 170 | 0.7319 | 0.1504 |
| 1 | 125 | 0.7872 | 0.1488 |

t-test for mean $p = 0.002$ (2 tailed)

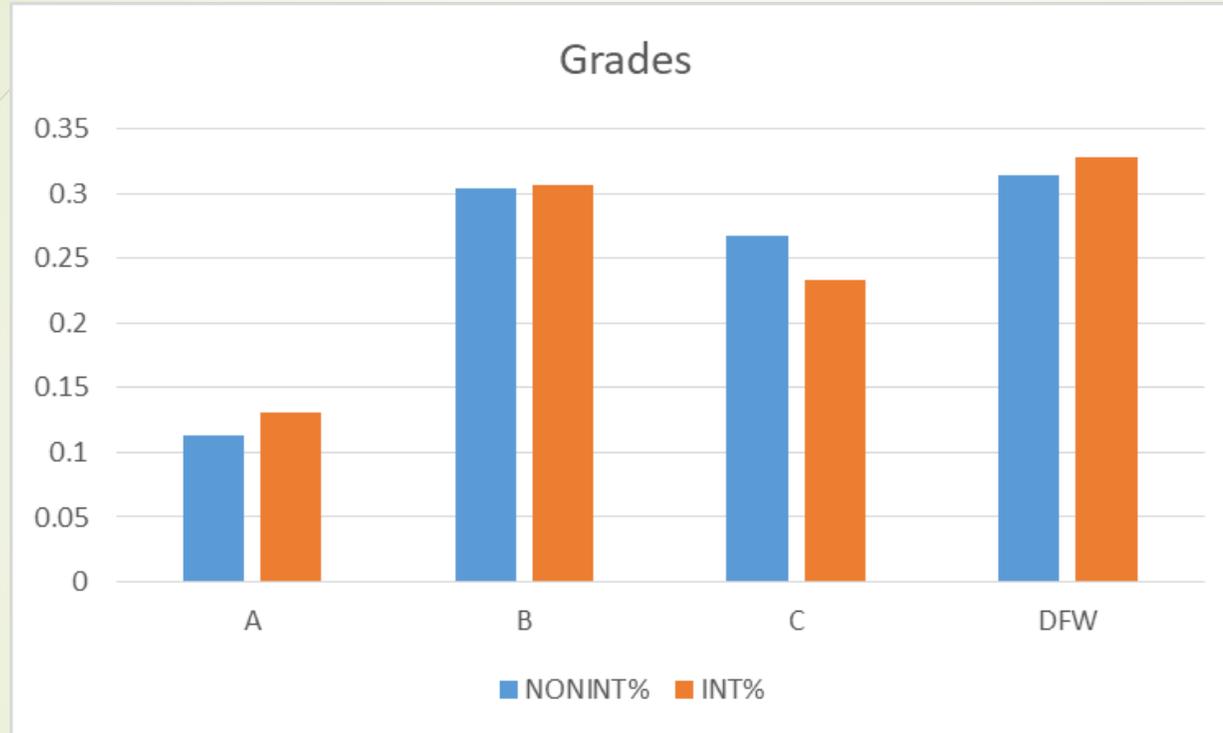
M100 Final Exam



| INT | N | Mean | Std. Dev |
|-----|-----|--------|----------|
| 0 | 163 | 0.6481 | 0.2010 |
| 1 | 113 | 0.7097 | 0.1493 |

t-test for mean $p = 0.004$ (2 tailed)

M100 FA2017



Course GPA was 0.3 higher in intervention sections
DFW rates were higher in intervention sections
One semester retention rate was 17% higher in intervention sections

Suggestions for Action



- Collect feedback from faculty surveys
- Compare DFW rates, scores on common midterm and final exams, class grades, grades in next STEM course between intervention classes and other classes that did not use active learning and also compare different cohorts