Active Learning Strategies for Math and Stat Problem Sessions

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Ten Maxims for Good Teaching

“A teacher affects eternity: She can never tell where her influence stops.”

1. Examine why you want to teach
2. Enter each class with specific goals and objectives
3. To feel confident, act confident
4. Enthusiasm and energy can carry the day
5. Use active learning strategies regularly

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1From “Confidence in the classroom: Ten maxims for new teachers” by James Eison, College Teacher, Vol 38, No. 1, pages 21-25
Ten Maxims for Good Teaching

“A teacher affects eternity: She can never tell where her influence stops.”

6. Ask for feedback from students and colleagues
7. Be relaxed about admitting when you don’t know
8. Learn the characteristics of effective teaching
9. Don’t be a perfectionist
10. Teach less, better

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2From “Confidence in the classroom: Ten maxims for new teachers”, by James Eison, College Teacher, Vol 38, No. 1, pages 21-25
Small Group Discussion

How do you conduct Problem Sessions?
What is active learning?³

1. Active learning involves students in
   - Doing things
   - Thinking about the things they are doing.

2. Active learning means getting involved:
   - Analyzing
   - Synthesizing
   - Evaluating

³“From sage on the stage to guide on the side”, A. King, College Teaching, 41 (1), p.30
What is active learning?

3. Active learning usually generates something new
   - e.g., a relationship between two ideas.

4. Students do not spontaneously engage in active learning.
   - They must be prompted to do so!

5. For each concept, structure an activity that requires students to generate meaning about that concept.

6. Students must use their own words and experiences.
Active learning works

MATH 2415
Small Group Active Learning Problem Sessions

Student survey [S16, 49 responses]
88% of respondents said attending problem sessions increased understanding and comprehension

Most effective learning:
1. Solving problems on past exams (2.64)
2. Solving homework problems on paper (2.59)
3. Solving problems in AL Problem Sessions (2.42)
4. Taking notes during lecture (2.37)

Least effective learning:
1. Reading the textbook (1.68)
2. Solving WebAssign homework problems (1.71)
Active learning works

Calculus Concept Inventory\(^4\)

- CCI is a \textbf{before/after} test of calculus \textbf{concepts}
- Concepts measured necessary for understanding
- Questions are utterly trivial for mathematicians
- CCI is a \textbf{test of courses} not of students

\[
g = \frac{\text{Gain in Class Performance}}{\text{Max Gain}}
\]

- \(g\) is independent of instructor
- \(g\) depends on instructional methodology:

\[g_{\text{InteractiveEngagement}} > g_{\text{Traditional}}\]

\(^4\)Epstein, Notices of AMS, (80), Sept 2013
Active learning works

Meta-analysis of active learning in STEM\textsuperscript{5}

1. Meta-analysis of 225 studies comparing
   - Active Learning (AL) courses
   - Traditional Lecture (TL) courses

2. Average exam scores 6% higher with AL

3. Improvement on Concept Inventories even better

4. Students in TL courses 1.5 times more likely to fail

\textsuperscript{5}Freeman et al., PNAS, (111), June 2014
Meta-analysis of active learning in STEM

Heterogeneity analyses indicated no statistically significant variation among experiments based on the STEM discipline of the course in question, with respect to either examination scores (Fig. 2A; $Q = 910.537$, df = 7, $P = 0.160$) or failure rates (Fig. 2B; $Q = 11.73$, df = 6, $P = 0.068$). In every discipline with more than 10 experiments that met the admission criteria for the meta-analysis, average effect sizes were statistically significant for either examination scores or failure rates or both (Fig. 2, Figs. S2 and S3, and Tables S1A and S2A). Thus, the data indicate that active learning increases student performance across the STEM disciplines.

For the data on examinations and other assessments, a heterogeneity analysis indicated that average effect sizes were lower when the outcome variable was an instructor-written course examination as opposed to performance on a concept inventory (Fig. 3A and Table S1B; $Q = 10.731$, df = 1, $P << 0.001$). Although student achievement was higher under active learning for both types of assessments, we hypothesize that the difference in gains for examinations versus concept inventories may be due to the two types of assessments testing qualitatively different cognitive skills. This explanation is consistent with previous research indicating that active learning has a greater impact on student mastery of higher- versus lower-level cognitive skills (6–9), and the recognition that most concept inventories are designed to diagnose known misconceptions, in contrast to course examinations that emphasize content mastery or the ability to solve quantitative problems (10). Most concept inventories also undergo testing for validity, reliability, and readability.

Heterogeneity analyses indicated significant variation in terms of course size, with active learning having the highest impact on courses with 50 or fewer students (Fig. 3B and Table S1C; $Q = 6.726$, df = 2, $P = 0.035$; Fig. S4). Effect sizes were statistically significant for all three categories of class size, however, indicating that active learning benefitted students in medium (51–110 students) or large (>110 students) class sizes as well.

When we metaanalyzed the data by course type and course level, we found no statistically significant difference in active learning’s effect size when comparing (i) courses for majors versus nonmajors ($Q = 0.045$, 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).
Types of active learning

1. **Blackboard work** by TA with active student input.

2. **Think-pair-share:**
   - TA poses a question
   - Students think about it
   - Pairs of students discuss thoughts
   - A few students share ideas with entire class

3. **Pair summarizing/checking**
   - One student explains a concept
   - Partner listens and provides constructive feedback
Types of active learning

4 Problem creation:
   - Each student poses a problem about a concept
   - Then exchange problems with a classmate and solve

5 Critiques: Find flaws in an argument made by TA.

6 Step-by-step:
   - Students break a problem up into several short steps
   - Then they fill in the steps

7 Small Group Active Learning: Details below!
Student comments on MATH 2415 evaluations

“The format where students do questions is very effective, and it definitely made doing the next weeks homework easier when I had already had the chance to struggle a little in the problem section.”
“I liked working with other students and presenting. It made the class a little more entertaining. I also learned from my classmates, and from their mistakes. Plus I was able to gauge if I was keeping up with the information by comparing myself to my peers.”
“The structure of the problem sessions was great. I participated in the class more and as a result learned more. I like the structure better than having a quiz at the end of class because I become engaged rather than just waiting for the quiz.”
MATH 2415 Instructional Team [’14-’16]

- **Faculty:** Sue Minkoff, Farid Khafizov, Changsong Li
- **GTA’s:** Sonny Skaaning, Yanping Chen, Fatih Gelir, Jing Guo, Abdullah Helal, Elvira Kadaub, Arafat Khan
- **UTeach Dallas TA’s:** Henry Curtis, Carl Finley, Dalia Franco Cortes, Andrew Marder, Mikaela McMurtry, Nikunj Patel, Matthew Portman, Erik Ringqvist, Jonathan Sok, Josilyn Valencia

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P.I.: Mary Urquhart (SME)
Calculus III at UT Dallas

- Two Calculus sequences:
  1. Fast pace: 2417, 2419
  2. Regular pace: 2413, 2414, 2415

- **MATH 2415**, Fall 2016 [230 students]:
  1. 3 Lecture Sections [2x75mins, 75 students]
  2. 7 Problem Sections [1 hr 50 mins, 33 students]
  3. Peer-Led Team Learning [80 mins, 70 students total]
  4. 3 Graduate TA’s
  5. 6 Undergraduate TA’s [Math majors in UTeach]

From vectors to Divergence Theorem

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7The course coordinator is a manager
8NSF funded
Active Learning Problem Sessions

- TA starts with 10 minute summary of lectures
- Then students actively solve assigned problems
- Students
  - Work in small groups of 3-4 at white boards
  - Explain solutions to each other and to TA’s
  - Photograph their solutions
- Teaching Assistants
  - Can’t hold white-board markers
  - Only ask questions, but can answer “yes” or “no”
  - Model student responses: "So you are saying...."

The room is buzzing with conversation.

9Undergraduates are pre-verbal mathematicians
Goals for student learners

1. Become effective problem solvers
   - via immediate, interactive feedback
   - via generation and evaluation of multiple approaches

2. Develop own conceptual understanding
   - in context of problem solving
   - by struggling in a mutually supporting environment
   - by being encouraged to go deeper
Small Group Active Learning: Goals

Goals for student learners

3. Develop ability to explain mathematics
   - confidently and succinctly
   - both concepts and solution techniques
   - using words and schematic diagrams
   - with feedback in form of probing questions

4. Grow into independent, active learners
   - by learning to ask own questions
   - by experiencing deeper conceptual understanding
Goals for student learners

5. Earlier and better preparation for exams
   - by assigning past exam problems 2+ weeks prior

6. Longer term retention of course material
   - since can explain concepts to others

7. Improved course grades
   - Center of mass has shifted from B-C to A-B.
How effective were you in helping the students and what would you do differently next time?

“I felt I was effective in helping the students, they felt comfortable in asking questions and admitting when they did not understand something. I would be more intentional about setting up a more open environment early on in the semester, I think that students did take a while to get comfortable with the format of the problem sessions and setting better defined expectations in the problem sessions early on could aid both the students and the teaching assistants.”
How effective were you in helping the students and what would you do differently next time?

“Yes, when I took the course I barely understood the material, and didn’t get the meaning of several concepts. However when I had to teach the material I realized several things that filled in the gaps of my understanding. Talking through the material made the material make sense.”
How effective were you in helping the students and what would you do differently next time?

“During the course I had a hard time judging if I was doing a good job but my midterm evaluations were overwhelmingly positive and a few of my students said I did a great job after the course was over.”
How did your role as an instructor influence your confidence in teaching?

“I also feel more confident teaching, I have learned a lot about the importance of intentional and meaningful questioning, and the value of having students explain their reasoning.”

“At first I was a bit shy, but soon developed confidence.”
Strategies for Asking Questions

1. Ask many questions at low cognitive levels
   - helps shore up prior basic skills

2. Ask some questions at high cognitive levels

3. **Wait** 3-5 seconds after asking a question

4. Encourage students to respond

5. Balance responses: volunteers and non-volunteers

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From *The Teaching Professor*, October 1994, p3.
Strategies for Asking Questions

6. Probe students responses
   - for clarification
   - to stimulate thinking

7. Acknowledge correct responses
   - Use praise genuinely, sparingly
   - Praise should be specific

8. Design questions so that $\approx 70\%$ answered correctly.

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11 From *The Teaching Professor*, October 1994, p3.
Leading Effective Discussions

1. Effective questioning [see above]
2. Active listening
   - important messages are conveyed by the way something is stated, including choice of words
3. Peripheral vision
   - involves ability to intuit group process
   - when to provide guidance, offer encouragement?
4. Empathy
   - ability to see there is more than one approach
5. Sense of timing: When to
   - ask a question
   - offer a summary
   - be silent

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From *The Teaching Professor, June/July 1995*
Leading Effective Discussions

6 Clarity

- move discussion forward with understanding
- involves restating “muffled” ideas

7 Differentiation

- leader cannot become totally absorbed by discussion

8 Variability

- Be light, serious, supportive, confrontational

9 Connecting with the class

- Reach each student, accounting for emotional, intellectual and physical states
Active Learning Sessions: Mechanics

1. Get buy-in from course instructors!

2. You need a room with lots of white boards!

3. TA brings markers and erasers

4. Students bring laptops to access
   - assignment sheet [more problems than most can do]
   - textbook
   - past exams

5. First 10 minutes **only**
   - TA reviews theory, soliciting questions and input
Active Learning Sessions: Mechanics

6 Students self-organize into small groups (3-4)
   - Change composition until all are working well

7 Group writes down problem # and statement

8 Students take photos of solutions

9 Each group explains some of their solutions to TA

10 When a group is stuck, TA asks probing questions

11 Vary approach depending on course, students
   - Can adapt to courses with quizzes
   - Caution: some students can’t work in groups

J. Zweck (UTD)
12 Use active learning right from start of course
   • with modest, achievable goals
13 Explain reasons for using active learning
14 Explain your expectations
15 After a couple of weeks session runs smoothly
How will you make more use of active learning this semester?