

What does active learning do?

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Definitions of Active Learning

Mathematical Proficiency and Student Learning Outcomes

Active Learning Techniques

Definitions of Active Learning

Various definitions exist in the literature, e.g.

- ▶ *Active Learning* (AL) is generally defined as any instructional method that engages students in the learning process. In short, active learning requires students to do meaningful learning activities and think about what they are doing.
- ▶ AL engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work.

There is not a unique definition of AL, either in popular use or in the research literature, and all existing definitions are inherently vague.

The Challenge of Defining AL

No simple definition of AL can simultaneously and effectively address the range of:

- ▶ AL techniques used across diverse classroom environments,
 - ▶ large-enrollment lectures with recitations, service learning, small-enrollment lecture, inquiry-based learning, online courses, etc
- ▶ institutional expectations for faculty in diverse employment contexts, and
 - ▶ long-term contract faculty, part-time or adjunct faculty, tenure-stream faculty, administrative staff, etc
- ▶ course and student learning outcomes across different institutions and departments.
 - ▶ general education, quantitative literacy, courses for non-STEM majors with quantitative requirements, courses for STEM majors, courses for mathematics majors

A Consequence

Faculty, administrators, public-policy makers, student advocates, and other stakeholders in postsecondary mathematics (and STEM) education frequently “talk past” each other when discussing AL.

I believe that better conversations occur when we define active learning by what it does in more specific contexts.

Mathematical Proficiency \implies
Student Learning Outcomes \implies
Definition of AL techniques

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Mathematical Proficiency at the K-12 level

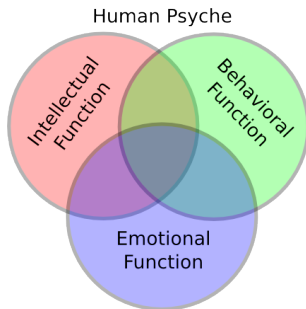
The 2001 NRC report *Adding It Up* emphasized a five “strand” model of proficiency, focused at the K-8 level:

- ▶ **Conceptual understanding:** comprehension of mathematical concepts, operations, and relations
- ▶ **Procedural fluency:** skill in carrying out procedures flexibly, accurately, efficiently, and appropriately
- ▶ **Strategic competence:** ability to formulate, represent, and solve mathematical problems
- ▶ **Adaptive reasoning:** capacity for logical thought, reflection, explanation, and justification
- ▶ **Productive disposition:** habitual inclination to see mathematics as sensible, useful and worthwhile, coupled with a belief in diligence and one’s own efficacy

I believe this framework also works well for courses in high school and the first two years of postsecondary mathematics education.

Psychological Domains

Modern psychology provides a basic framework of the human psyche with three domains. The five-strand model of proficiency, among others, reflects this framework.



Aside: Many math courses focus primarily on “Intellectual” aspects of student learning. Most AL techniques engage students across two or three of these domains.

Other Examples

Other prominent standards/reports/guides make recommendations that reflect a broad vision of mathematical proficiency, e.g.:

- ▶ The Common Core State Standards for Mathematics includes both Standards for Mathematical Practice and Grade-Level Content Standards.
- ▶ The 2015 MAA CUPM Curriculum Guide to Majors in the Mathematical Sciences provides four “Cognitive” goals for major programs and nine “Content” goals for major programs.

Student Learning Outcomes

Every course should have clear *Student Learning Outcomes* (SLOs) that represent all of the psychological domains and all of the components of a robust framework for mathematical proficiency.

For example, at the University of Kentucky, Number Theory serves as an “intro to proof” course. Our department voted to recommended the following SLOs to faculty teaching the course.

Students will deepen their understanding of the following topics and improve with regard to the following practices:

1. Divisibility, Division Algorithm, Euclidean Algorithm
2. Fundamental Theorem of Arithmetic, Infinitude of Primes
3. Linear Congruences, Chinese Remainder Theorem
4. Fermat's Little Theorem, Wilson's Theorem
5. Direct Proof, Proof by Contradiction, Mathematical Induction
6. Being persistent, Working through perceived failure, Strategic self-questioning
7. Productive collaboration with others, Asking good questions
8. Constructing examples and non-examples to investigate and understand new definitions and theorems
9. Reading and understanding existing proofs, Recognizing incorrect proofs
10. Developing and communicating original proofs

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A Course-Specific Definition of Active Learning

In a given course, an *active learning method* is a classroom teaching technique in which students complete a task or activity directly supporting development in

1. one or more student learning outcomes,
2. one or more domains of mathematical proficiency, and
3. one or more psychological domains.

Our goal for each course should be to incorporate multiple AL techniques that collectively support development across all of our SLOs, domains of mathematical proficiency, and psychological domains.

AL Example #1: Procedural computation in large-lecture Calculus I

To support: intellectual domain, procedural fluency, ability to use derivatives

Technique: When working a simple example, take one minute to have the students compute the derivative of a polynomial independently.

AL Example #2: Think-Pair-Share in small-lecture Number Theory

To support: behavioral and emotional domains, conceptual understanding, productive disposition, productive collaboration with others

Technique: Ask students to use Euclid's proof of the infinitude of primes to produce as many new prime numbers as possible starting with only the prime 3. Students have three minutes to compute independently, then three minutes spent comparing their results with one or two of their neighbors in class, discussing the reason for why their lists are the same or different.

AL Example #3: IBL-style small group activity in Number Theory

To support: all psychological domains, conceptual understanding, productive disposition, working through perceived failure, reading and understanding proofs

Technique: Assign students to small groups. Give each group a theorem with a 15-line proof where each line is separately cut out and mixed together, where the proof has one (fixable) error. Students must first collaboratively reconstruct the proof, then identify and correct the error.

An Important Question

Q: While the literature has many papers studying the aggregate impact of an AL technique, how do we determine whether or not a specific teaching technique in a specific classroom environment supports a specific SLO, proficiency domain, or psychological domain?

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Q: While the literature has many papers studying the aggregate impact of an AL technique, how do we determine whether or not a specific teaching technique in a specific classroom environment supports a specific SLO, proficiency domain, or psychological domain?

A: I don't know. To my knowledge, at this time many faculty using many AL techniques make these choices based on experience, intuition, and educated guesses informed by research in math education and psychology.

I would be interested to know if any studies have been attempted that investigate AL techniques at this more refined level.

Thank you for listening!