Active Learning 101
Why and How to Get Started

Michael S. Kirkpatrick
CFI New Faculty Orientation
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“Learning is...”
Learning is...
Learning is…

Knowledge

CHANGE

Abilities

Attitudes
Learning is...

AREA OF INQUIRY

- Context
- Factual knowledge

Knowledge
- Application

Abilities
- CHANGE

Attitudes
Learning is…

**AREA OF INQUIRY**
- Retrieval
- Application
- Factual knowledge

**CHANGE**
- Knowledge
- Abilities
- Attitudes

**METACOGNITION**
- Feedback
- Progress
- Practice

Active Learning 101: Why and How to Get Started
JMU Center for Faculty Innovation
A short quiz

**True or False:**
1. Good learning makes us feel confident and clear.
2. Learning can occur without intentional effort.
3. You have to be interested and motivated to learn.
4. Intelligent people learn more easily.
5. Adapting instruction based on learning styles has no effect on learning.
6. Rereading textbooks efficiently reinforces concepts and leads to greater mastery.

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“Adopting instructional practices that engage students in the learning process is the defining feature of active learning.”

–Michael Prince
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Why active learning?

Pre- vs. post- in physics

- Mechanics Diagnostic
- Force Concept Inventory
- Multiple institutions
- 62 courses (14 trad.)
- 6542 students (2084)

http://www.physics.indiana.edu/~sdi/aipv3i.pdf
Why active learning?

Closing the gender gap

- Pre-test scores different
- Gap persisted with lecture
- IE+ post-test equal


T: traditional lectures
IE: interactive lectures
IE+: interactive assignments, lectures, tutorials
Why active learning?

Closing the gender gap

- Pre-test scores different
- Gap persisted with lecture
- IE+ post-test equal
- Requires more than just interactive lecture

Why active learning?

Metaanalysis

- 158 studies (exams/CIs)
  - 0.47 SDs on scores
  - 6% course grade
- 67 studies (failure rate)
  - 33.8% → 21.8%

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; \(Q = 910.537, \text{df} = 7, \text{P} = 0.160\)) or failure rates (Fig. 2B; \(Q = 11.73, \text{df} = 6, \text{P} = 0.068\)). 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; \(Q = 10.731, \text{df} = 1, \text{P} << 0.001\)). 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; \(Q = 6.726, \text{df} = 2, \text{P} = 0.035\); 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 effects when comparing (i) courses for majors versus nonmajors (\(Q = 0.045, \text{df} = 1, \text{P} = 0.883\); Table S1D), or (ii) introductory versus upper-division courses (\(Q = 0.046, \text{df} = 1, \text{P} = 0.829\); Tables S1E and S2D).

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Why active learning?
But, um, aren’t you...
Human cognitive architecture
Human cognitive architecture

- Amassing Information store
- Long-term memory
Human cognitive architecture

Amassing

Information store

Long-term memory
Human cognitive architecture
Human cognitive architecture

Amassing
Information store

Acquiring

[Image of a human head with a network diagram inside, representing the Amassing and Acquiring processes.]
Human cognitive architecture
Human cognitive architecture

- Amassing
  - Information store
- Acquiring
  - Borrowing/reorganizing
Human cognitive architecture

- Amassing:
  - Information store

- Acquiring:
  - Borrowing/reorganizing
  - Randomness as genesis
Human cognitive architecture

- **Amassing**
  - Information store

- **Acquiring**
  - Borrowing/reorganizing
  - Randomness as genesis
Human cognitive architecture

- **Amassing**
  - Information store

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Human cognitive architecture

Amassing
- Information store

Acquiring
- Borrowing/reorganizing
- Randomness as genesis

Interaction
Human cognitive architecture

- **Amassing**
  - Information store

- **Acquiring**
  - Borrowing/reorganizing
  - Randomness as genesis

- Interaction

- Working memory
Human cognitive architecture

Amassing
- Information store

Acquiring
- Borrowing/reorganizing
- Randomness as genesis

Interaction
- Narrow limits of change

Working memory
Human cognitive architecture

Amassing
- Information store

Acquiring
- Borrowing/reorganizing
- Randomness as genesis

Interaction
- Narrow limits of change

Working memory
Human cognitive architecture

- **Amassing**
  - Information store

- **Acquiring**
  - Borrowing/reorganizing
  - Randomness as genesis

- **Interaction**
  - Narrow limits of change

**Working memory**
Human cognitive architecture

- Amassing:
  - Information store

- Acquiring:
  - Borrowing/reorganizing
  - Randomness as genesis

- Interaction:
  - Narrow limits of change

Working memory
Human cognitive architecture

Amassing
- Information store

Acquiring
- Borrowing/reorganizing
- Randomness as genesis

Interaction
- Narrow limits of change

Working memory

WM Capacity:
- 4-7 items (2-3 novel)
- 20 seconds maximum
Human cognitive architecture

- **Amassing**
  - Information store

- **Acquiring**
  - Borrowing/reorganizing
  - Randomness as genesis

- **Interaction**
  - Narrow limits of change
Human cognitive architecture

- **Amassing**
  - Information store

- **Acquiring**
  - Borrowing/reorganizing
  - Randomness as genesis

- **Interaction**
  - Narrow limits of change

- **Central executive**
- **Auditory loop**
- **Visual-spatial sketchpad**
Human cognitive architecture

Amassing
- Information store

Acquiring
- Borrowing/reorganizing
- Randomness as genesis

Interaction
- Narrow limits of change
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Human cognitive architecture

- Amassing
  - Information store

- Acquiring
  - Borrowing/reorganizing
  - Randomness as genesis

- Interaction
  - Narrow limits of change
  - Environmental linking
Human cognitive architecture

- **Amassing**
  - Information store

- **Acquiring**
  - Borrowing/reorganizing
  - Randomness as genesis

- **Interaction**
  - Narrow limits of change
  - Environmental linking
Human cognitive architecture

- **Amassing**
  - Information store

- **Acquiring**
  - Borrowing/reorganizing
  - Randomness as genesis

- **Interaction**
  - Narrow limits of change
  - Environmental linking
Far transfer

Apply the Pythagorean theorem to the above triangle to find the value of $x$. 

\[
\begin{align*}
90 \text{ ft} & \quad x \\
90 \text{ ft} & \quad 90 \text{ ft}
\end{align*}
\]
Far transfer

Apply the Pythagorean theorem to the above triangle to find the value of $x$.

In a baseball diamond, the distance between each base is 90 ft. Which of the following is true about the shortest distance between 1st and 3rd bases (the red line shown above)?

1. It is less than 90 ft.
2. It is between 90 and 120 ft.
3. It is greater than 120 ft.
Which of these principles of human cognition best explains why active learning is more effective than traditional lecture?

A. Information store
B. Borrowing and reorganizing
C. Randomness as genesis
D. Environmental linking
Two systems of thinking

**System 1 - Automatic**

Quick
Effortless
Involuntary
Associative
Two systems of thinking

**System 1 - Automatic**
- Quick
- Effortless
- Involuntary
- Associative

**System 2 - Effortful**
- Lazy controller
- Calculations
- Critical thinking
Types of knowledge

- Biologically Primary
- Biologically Secondary
Types of knowledge

- Biologically Primary
- Biologically Secondary
Types of knowledge

Biologically Primary

Biologically Secondary

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Retrieval fluency

Retrieval fluency

Retrieval fluency

Retrieval fluency

In one study, a chess master, a Class A player (good but not a master), and a novice were given 5 seconds to view a chess board position from the middle of a chess game; see Figure 2.1. After 5 seconds the board was covered, and each participant attempted to reconstruct the board position on another board. This procedure was repeated for multiple trials until everyone received a perfect score. On the first trial, the master player correctly placed many more pieces than the Class A player, who in turn placed more than the novice: 16, 8, and 4, respectively.

However, these results occurred only when the chess pieces were arranged in configurations that conformed to meaningful games of chess. When chess pieces were randomized and presented for 5 seconds, the recall of the chess master and Class A player were the same as the novice—they placed from 2 to 3 positions correctly. Data over trials for valid and random middle games are shown in Figure 2.2.

**FIGURE 2.2** Recall by chess players by level of expertise.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Master</th>
<th>Class A player</th>
<th>Beginner</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>10</td>
<td>8</td>
</tr>
</tbody>
</table>

Retrieval fluency

Cognitive Load Theory
Cognitive Load Theory

Low Intrinsic Load
Cognitive Load Theory

High Intrinsic Load

Low Intrinsic Load
Cognitive Load Theory

- High Intrinsic Load
- Low Intrinsic Load
- Extraneous Load
Cognitive Load Theory

- High Intrinsic Load
- Low Intrinsic Load
- Extraneous Load
- Germane Load
Cognitive Load Theory
Cognitive Load Theory

Goal-free effect
Cognitive Load Theory

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Cognitive Load Theory
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Cognitive Load Theory

- Goal-free effect
- Modality effect
- Worked example effect
- Variability effect
- Redundancy effect
- Expertise reversal effect
Worked example effect
Worked example effect

**Step 1: Identify the shapes**
There are two right triangles with sides that are 90 ft and the red line as hypotenuse.

**Step 2: Recall the formula**
Pythagorean theorem:
\[ a^2 + b^2 = c^2 \]

**Step 3: Substitute known values**
\[ 90^2 + 90^2 = c^2 \]

**Step 4: Solve for c**
\[ 8100 + 8100 = c^2 \]
\[ 16,200 = c^2 \]
\[ \sqrt{16,200} = \sqrt{c^2} \]
\[ 90 \sqrt{2} = c \]

**Step 5: Make a selection**
Since \( 1 < \sqrt{2} < 2 \), \( 90 < c < 180 \), so the correct answer is (2) between 90 and 180 ft.

In a baseball diamond, the distance between each base is 90 ft. Which of the following is true about the shortest distance between 1st and 3rd bases (the red line shown above)?

1. It is less than 90 ft.
2. It is between 90 and 120 ft.
3. It is greater than 120 ft.
Variability effect

Calculate distance between (1,1) and (4,5)

**Step 1: Identify the facts**
Distance is the length of a hypotenuse, for a triangle with sides as the change in x and the change in y.

**Step 2: Recall the formula**
Pythagorean theorem:
\[ a^2 + b^2 = c^2 \]

**Step 3: Substitute known values**
\[ (4-1)^2 + (5-1)^2 = c^2 \]

**Step 4: Solve for c**
\[ 3^2 + 4^2 = c^2 \]
\[ 9 + 16 = c^2 \]
\[ 25 = c^2 \]
\[ 5 = c \]
Variability effect

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Low variability:
Find distance between (2,3) and (8,11).
Variability effect

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Medium variability:
Find distance between (2,1) and (x,13).
Variability effect

**Calculate distance between (1,1) and (4,5)**

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**Low variability:**
Find distance between (2,3) and (8,11).

**Medium variability:**
Find distance between (2,1) and (x,13).

**High variability:**
Find (x,y) that has distance of 5 from (3,4).
Redundancy effect

The redundancy effect occurs when information is presented in a way that includes redundant material. One example of this is to present the same idea using both visual and executive modalities, such as reading from a PowerPoint slide that has a lot of text on it. The text itself is processed initially as visual imagery, then as auditory as we “read aloud” to ourselves internally. This induces extraneous cognitive load as our minds have to cross-reference the three forms to make sure they are the same. The effect is made worse when the instructor’s voice is also reading the words. Those words must also be cross-checked for accuracy. In the end, the information is lost before it can be transferred to LTM.
Notice anything?
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Don’t abandon UDL
Expertise reversal effect

**Novice**
- Vertical—compartmentalized
- Lack of linkages requires inefficient trial and error search and slow retrieval

**Expert**
- Horizontal—networked
- Dense neural networking allows quick scan and rapid retrieval
GOOD

R

I

S

E
GOOD
Retrieval practice
Interleaving
S
E
GOOD
Retrievial practice
Interleaving
Spacing
E
GOOD
R (retrieval practice)
I (interleaving)
S (spacing)
E (elaboration)
GOOD
Retrieval practice
Interleaving
Spacing
Elaboration

Deliberative effort
Pre-learning
Growth mindset
Metacognition
GOOD

Retrieval practice
Interleaving
Spacing
Elaboration

Deliberative effort
Pre-learning
Growth mindset
Metacognition

BAD

PRIL

MA

P R I M A L
<table>
<thead>
<tr>
<th>GOOD (Green)</th>
<th>BAD (Red)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retrieval practice</td>
<td>Passive observation</td>
</tr>
<tr>
<td>Interleaving</td>
<td></td>
</tr>
<tr>
<td>Spacing</td>
<td></td>
</tr>
<tr>
<td>Elaboration</td>
<td></td>
</tr>
</tbody>
</table>

- Deliberative effort
- Pre-learning
- Growth mindset
- Metacognition

Deliberative effort
Pre-learning
Growth mindset
Metacognition
GOOD

Retrieval practice
Interleaving
Spacing
Elaboration

Deliberative effort
Pre-learning
Growth mindset
Metacognition

BAD

Passive observation
Rereading texts
MAL
GOOD
Retrieval practice
Interleaving
Spacing
Elaboration

BAD
Passive observation
Rereading texts
Intuitive judgments
Mal

Deliberative effort
Pre-learning
Growth mindset
Metacognition
GOOD
R - Retrieval practice
I - Interleaving
S - Spacing
E - Elaboration

BAD
P - Passive observation
R - Rereading texts
I - Intuitive judgments
M - Massed practice
L

Deliberative effort
Pre-learning
Growth mindset
Metacognition
**GOOD**

Retrieval practice
Interleaving
Spacing
Elaboration

- Deliberative effort
- Pre-learning
- Growth mindset
- Metacognition

**BAD**

Passive observation
Rereading texts
Intuitive judgments
Massed practice
Learning styles
Assessment jigsaw

When is it good to use?
What is the effort and impact?
How does it RISE?
Recommended reading