When is Too Much Not Enough?
Using Cognitive Theories of Learning to Shape Instructional Choices

Michael S. Kirkpatrick
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What is “learning?”
### Einstellung

<table>
<thead>
<tr>
<th>Sample</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>29</td>
<td>3</td>
<td></td>
<td>20</td>
</tr>
</tbody>
</table>

### Solution Explanation:

\[
29 - 3 - 3 - 3 = 20
\]

### Experimental Solution:

\[
B - A - C - C = \text{Target}
\]

---


Einstellung

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Einstellung 1</td>
<td>29</td>
<td>3</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Einstellung 2</td>
<td>14</td>
<td>127</td>
<td>3</td>
<td>100</td>
</tr>
<tr>
<td>Einstellung 3</td>
<td>18</td>
<td>43</td>
<td>25</td>
<td>99</td>
</tr>
<tr>
<td>Einstellung 4</td>
<td>9</td>
<td>42</td>
<td>6</td>
<td>21</td>
</tr>
<tr>
<td>Einstellung 5</td>
<td>20</td>
<td>59</td>
<td>4</td>
<td>31</td>
</tr>
</tbody>
</table>

Einstellung Solution:  
49 - 23 - 3 - 3 = 20

Direct Solution:  
23 - 3 = 20

<table>
<thead>
<tr>
<th></th>
<th>Critical 1</th>
<th>Critical 2</th>
<th>Critical 3</th>
<th>Critical 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>23</td>
<td>15</td>
<td>18</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>49</td>
<td>39</td>
<td>48</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Target</td>
<td>20</td>
<td>18</td>
<td>22</td>
<td>6</td>
</tr>
</tbody>
</table>

### Einstellung

<table>
<thead>
<tr>
<th>Einstellung (percent)</th>
<th>Direct (percent)</th>
<th>No solution (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (children)</td>
<td>1</td>
<td>89</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental (children)</td>
<td>72</td>
<td>24</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control (adults)</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental (adults)</td>
<td>74</td>
<td>26</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Branches of Educational Psychology

- Behavioral (Skinner)
- Cognitive (Bjork, Sweller)
- Constructivism (Vygotsky, Bruner)
- Developmental (Piaget)
Learning is...

- Abilities
- Change
  - Context
  - Retrieval
  - Progress
  - Metacognition
  - Practice
- Attitudes
- Factual knowledge
- Area of inquiry
- Application
- Knowledge
Learning is...misunderstood

Common myths about learning:

- Good learning makes us feeling confident and clear.
- Learning is aware and purposeful.
- Getting emotional interferes with learning.
- You have to be interested to learn.
- Intelligent people learn more easily.
- Learning style adaptations are helpful.
- Rereading texts is helpful.

In-class Physics Demos

The evidence supporting active learning suggests that passive engagement with information can contribute to reinforcing misconceptions. One study examined how effective in-class physics demonstrations were in helping to understand concepts. All students began with a reading assignment. Some students then took part in an in-class demonstration; the control group did not observe or take part in a demonstration. The students completed a short test to conclude the experiment. Which group did the worst on the post-test, missing the most points?
In-class Physics Demos

Which group did the **worst** on the post-test, missing the most points?

(A) Students who did not observe a demo (control group)
(B) Students who only observed the demo
(C) Students who predicted the outcome before it occurred by writing down a guess
(D) Students who discussed the outcome with peers after observing what occurred

![Table]

<table>
<thead>
<tr>
<th>Mode</th>
<th>Correct</th>
<th>Incorrect</th>
</tr>
</thead>
<tbody>
<tr>
<td>no demo</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>observe</td>
<td>18%</td>
<td>82%</td>
</tr>
<tr>
<td>predict</td>
<td>29%</td>
<td>71%</td>
</tr>
<tr>
<td>discuss</td>
<td>30%</td>
<td>70%</td>
</tr>
</tbody>
</table>

E. Mazur, Keynote address at ICER 2011.
Knowledge and human cognitive architecture
Types of Knowledge

Biologically Primary

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Biologically Secondary

---

 ✓

✗

✓

✗
Retrieval Fluency

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 180 ft.
3. It is greater than 180 ft.
Memory Architecture
Human Cognitive Architecture

Amassing
- Information store

Acquiring
- Borrowing/reorganizing
- Randomness as genesis

Interaction
- Narrow limits of change
- Environmental linking

Central executive memory

Auditory loop

Visual-spatial

Working memory (WM)
- 4-7 items (2-3 novel)
- 20 seconds maximum

Long-term memory
Key findings

What works:

• Deliberative effort
• Interleaved and spaced practice
• Try to solve problem before being taught
• Testing as calibration
• Pre-learning foundation
• Elaborative encoding

What doesn’t:

• Massed practice
• Rereading texts
• Learning style adaptations
• Intuitive judgments

Cognitive load theory and its effects
Cognitive Load Theory

- High Intrinsic Load
- Low Intrinsic Load

- Extraneous Load
- Germane Load

Goal-free effect
Modality effect
Worked example effect
Imagination effect
Variability effect
Transient info effect
Redundancy effect
In a baseball diamond, the distance between 90 ft and 180 ft.

**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.
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
\[ 3^2 + 4^2 = c^2 \]
\[ 9 + 16 = c^2 \]
\[ 25 = c^2 \]
\[ 5 = c \]

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?
Redundancy Effect

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Applications of effects

- Testing effect
- Goal-free effect
- Worked example effect
- Imagination effect
- Modality effect
- Variability effect
- Redundancy effect
- Transient info effect
Expertise reversal and guidance fading effects
Questions?