Learning by Teaching

Overview

- Purpose:
  - `To determine how and why “learning by teaching” helps students learn, specifically, to separate the effects of:
    - Teaching Expectancy (preparing to teach), and
    - Actual Teaching (explaining content to others)
- The researchers wanted to see:
  - Does simply preparing to teach help learning?
  - Does actually teaching provide additional benefits?
  - Do these benefits last over time?

Background

- Learning by teaching is widely believed to be powerful. Many educational practices assume it works (peer tutoring, group discussions, etc.)
- But:
  - It wasn't clear which part of the teaching process creates learning.
  - Past studies often didn't compare preparing vs. actually teaching.
  - Some defined "teaching" broadly and included interactions with real students, making effects unclear.
  - This study isolates the two components and uses both immediate and delayed tests.

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  - Does actually teaching provide additional benefits?
  - Do these benefits last over time?
- Hypotheses:
  - Preparing to teach will improve immediate comprehension (because students select and organize material).
  - Actually teaching will lead to deeper learning and better long-term retention by prompting elaboration and integration.
  - Over time, differences will become more obvious (delayed test).

Study Design

- Participants
  - Undergraduate psychology students with low prior knowledge of the Doppler Effect.
  - Experiment 1, sample size: 93
  - Experiment 2, sample size: 75
- Learning Material
  - A short (600-word) multimedia lesson on the Doppler Effect.
- Conditions
  - Control: Study the lesson normally, told they will take a test but there is no teaching expectation
  - Preparation (Teaching Expectancy): Told they will teach the lesson, given 10 minutes to prepare but do NOT actually teach before test
  - Teaching: Told they will teach, prepare for 10 minutes and then teach a 5-minute video-recorded explanation as if teaching another student

Study Design

- Assessment
  - Experiment 1: Immediate comprehension test
  - Experiment 2: Same test after 1-week delay
- Test = Six free-response conceptual questions (max 25 points)

Results

- Experiment 1
  - Preparing to teach already improves learning.
  - Teaching improves learning but not significantly more than preparation on the immediate test.

Both preparation and teaching groups learned more than control:

Group	Mean Score	Effect Size vs. Control
Control	6.2	—
Preparation	7.9	**d = 0.59**
Teaching	8.7	**d = 0.82**

Results

- Experiment 2
  - The benefit of preparing to teach disappears after a week.
  - But the benefit of actually teaching persists strongly.
  - Teaching leads to deeper, more durable understanding.

Group	Mean Score	Effect Size vs. Control
Control	5.0	—
Preparation	5.6	d = 0.24 (not significant)
Teaching	7.3	**d = 0.79**

Concreteness Fading

Overview

- Concreteness fading:
  - beginning learning with concrete representations and gradually moving to abstract representations
  - Start concrete ➜ move to perceptually simplified ➜ move to abstract
- Purpose:
  - To examine whether concreteness fading helps improve children’s understanding and transfer of mathematical concepts.

Overview

- Concrete representations
  - Easy to understand
  - Connect to children's real-world experiences
  - BUT: Children may focus on irrelevant surface features
  - AND: May struggle to transfer learning to new contexts
- Abstract representations (e.g., numerals, equations)
  - Great for generalization
  - Stripped of distracting details
  - BUT: Hard for children to initially understand
  - Require cognitive resources and prior knowledge
- How do we get the benefits of both without the drawbacks?

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Key Principles of Concreteness Fading

1. Concrete Stage
    a. Use manipulatives, objects, real-life contexts
    b. Purpose: Build a meaningful intuitive base
2. Perceptually Simplified Stage
    a. Strip away irrelevant features
    b. Use simple diagrams or shaded circles
    c. Purpose: Help students focus on relational structure
3. Abstract Stage
    a. Symbols, equations, generalized rules
    b. Purpose: Support flexible, transferable reasoning

- They emphasize that the progression is essential.
- Jumping directly to abstract or staying too long in concrete both create learning problems.

Experiment 1

- Purpose:
  - To test whether concreteness fading helps children learn mathematical equivalence more effectively than learning with only concrete or only abstract materials.
- Sample:
  - N = 87 children
  - 1st–3rd graders
  - From elementary-school classrooms
- Design:
  - A between-subjects experimental design with three instructional conditions:
    - Concrete Only – children learned with physical blocks
    - Faded – children learned with physical blocks ➔ then pictorial diagrams ➔ then abstract equations
    - Abstract Only – children learned with numbers and symbols only
  - All children solved mathematical equivalence problems (e.g., 7 + 2 + 5 = 7 + __).

Experiment 1

- Procedure:
  - Pretest
    - A set of mathematical equivalence problems to measure children's baseline understanding
  - Learning Phase (Manipulated Across Conditions)
    - Concrete Condition: manipulative blocks
    - Abstract Condition: number equations
    - Faded Condition: blocks ➔ simplified schematic drawings ➔ equations
  - Posttest
    - Children solved new equivalence problems
    - Purpose: assess transfer and conceptual gains

Experiment 1

- Main findings:
    -

Experiment 1

- Main findings:
  - Faded Condition > Concrete Only
  - Faded Condition > Abstract Only
  - Children in the Faded group significantly outperformed both other groups on the posttest.

Experiment 3

- Purpose:
    - Experiment 3 examined whether starting with abstract and moving toward concrete (reverse-fading) would produce the same benefit.
- Sample:
    - N = 89 children
    - 1st–3rd graders
- Design:
    - A between-subjects design with three conditions:
        - Faded Condition (Concrete → Pictorial → Abstract)
        - Reverse-Faded Condition (Abstract → Pictorial → Concrete)
        - Abstract Only Condition
    - This allows the researchers to isolate whether direction of fading matters.

Experiment 3

- Procedure:
  - Pretest
    - Same mathematical equivalence assessment as Experiment 1
  - Learning Phase
    - Faded Group: concrete blocks → simplified drawings → symbolic equations
    - Reverse-Faded Group: symbolic equations → simplified drawings → concrete blocks
    - Abstract Group: equations only
  - Posttest
    - Same format as Experiment 1: all-abstract equivalence problems

Experiment 3

- Main findings:

Experiment 3

- Main findings:
  - Only the Faded group showed strong improvement.
  - Reverse-faded group performed similarly to the abstract-only group.
  - The benefit happens because the sequence moves from concrete → abstract, supporting progressive abstraction.
  - Starting abstract and moving to concrete does not help and may even confuse learners.

Implications

- Begin with concrete examples but avoid staying there forever
- Gradually guide students toward abstraction
- Explicitly connect each stage (e.g., “This drawing represents these blocks…”)
- Use multiple concrete examples, not just one
- Draw attention to structure, not surface details
- Use fading not as a rigid script but as an adaptable framework
- Limitations:
    - The ideal pace of fading is still unknown
    - Different topics may require different fading sequences
    - Children may need explicit instruction on how representations connect