Can you improve thinking skills in physics classes?

Why do students think about physics this way?

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UH Clear Lake Mar 2011
Problems!

- Disjointed & too much curriculum
- Conventional Lectures have low effectiveness
- Verification labs promote “going through the motions.”
- Inadequate thinking skills
  - 25% of advanced HS students &
  - 75% of regular HS students lack proportional reasoning ability
Dimming down: How the brainpower of today's 14-year-olds has slipped 'radically' in just one generation

- 26th October 2008 UK
- Previous research by Professor Shayer has shown that 11-year-olds' grasp of concepts such as volume, density, quantity and weight appears to have declined over the last 30 years. Their mental abilities were up to three years behind youngsters tested in 1975.
- Similar results in US
Testing in HS

- “Forces and Motion Conceptual Evaluation” (FMCE)
- Gain calculated $<G> = \frac{\text{post-pre}}{\text{max-pre}}$

What they learned/What they didn’t know

- Thinking Skills test (TS) “Classroom test of Scientific Reasoning” by Anton Lawson from “Science Teaching and the Development of Reasoning”
FMCE GAIN LIMITED BY TS

Concrete oper.  Transitional  Formal

F&M <G>

TS pre

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<th>60</th>
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Graph showing the relationship between TS pre and FMCE gain limited by TS.
It appears that the maximum percentage gain on the Force and Motion conceptual evaluation is limited to 10 times the score on the Lawson pretest.

Lawson scores translate:
0-4 concrete operational (age 9-) 30% of public
5-8 transitional
9-12 formal operational (possible at age 10+)

**Students need Cognitive Enhancement!**
Cognitive Enhancement

- Reuven Feuerstein – *Instrumental Enrichment*
- Shayer, Adey, Yates – *Thinking Science*
  - Time (70 min treatment/ 2 weeks)
  - Separate from regular class!
  - Concrete preparation
  - Exploration, cognitive conflict
  - Construction (concept development)
  - Metacognition
  - Bridging (Application)

Very similar to Learning cycle
Lawson Test Breakdown

1. Weight conservation 84%
2. Volume conservation 58
3. Proportionality 42
4. Adv Proportion 52
5. Control Var 1 95
6. Control Var 2 95
7. 2 Var 31
8. 2 Var advanced 26
9. Probability 89
10. Probability adv 63
11. Combinatorial 16
12. Statistical 16
# Lawson Test Breakdown

1. **Weight conservation**  
   - **Percentage:** 84%  
   - **Gain:** 100

2. **Volume conservation**  
   - **Value:** 58  
   - **Value:** 68  
   - **Difference:** 24

3. **Proportionality**  
   - **Value:** 42  
   - **Value:** 63  
   - **Difference:** 34

4. **Adv Proportion**  
   - **Value:** 52  
   - **Value:** 57  
   - **Difference:** 10

5. **Control Var 1**  
   - **Value:** 95  
   - **Value:** 95  
   - **Difference:** 0

6. **Control Var 2**  
   - **Value:** 95  
   - **Value:** 100  
   - **Difference:** 100

7. **2 Var**  
   - **Value:** 31  
   - **Value:** 47  
   - **Difference:** 23

8. **2 Var advanced**  
   - **Value:** 26  
   - **Value:** 42  
   - **Difference:** 24

9. **Probability**  
   - **Value:** 89  
   - **Value:** 89  
   - **Difference:** 0

10. **Probability adv**  
    - **Value:** 63  
    - **Value:** 63  
    - **Difference:** 0

11. **Combinatorial**  
    - **Value:** 16  
    - **Value:** 21  
    - **Difference:** 6

12. **Statistical**  
    - **Value:** 16  
    - **Value:** 32  
    - **Difference:** 19
Modeling

- Concrete preparation – brainstorm variables
- Exploration – Do experiment & find equation
- Concept development – wrap up some bridging
- Application & bridging - problems
Proportional thinking

• Modeling used “old fashioned” graph linearization to get straight line fit.
• In other words recognize a “squared relationship”
• Make test graph of ordinate vs abscissa squared, and use Y=mx + b
• Strong interpretation – what is meaning of slope? Never ΔY/ΔX, or V for X vs t
What is new?

• In HS did not see this dramatic change
• Added metacognitive features
• I talked about how proportional thinking is not doing ratios, but also recognizing ratios.
Midway through the exam, Allen pulls out a bigger brain.
REFERENCES

• Lawson - *Science Teaching and the Development of Thinking*
• Shayer, Adey – *Really Raising Standards*
• Fuller, Campbell, Dykstra, Stevens – *College Teaching and the Development of Reasoning*
• Feuerstein – *Instrumental Enrichment* (1980)
• Video – shows students reasoning!
  digitalcommons.unl.edu/adaptworkshopmodule4/2/