Going Beyond Rote:
Training and Testing for Explained Thinking

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My Teaching Philosophy Highlights

1. High expectations
2. Active engagement
3. Teach the “hidden curriculum”
    - Skills, not just topics
    - Philosophy of the discipline
    - Affective domain
    - Metacognition
4. Feedback
    - Early, often, in detail
5. Engineer the classroom
    - Begin with course goals
    - Watch for efficiencies and restraints

Course goals

SLO from Earth Science:

"Use general principles to explain natural phenomena"

SLO from GE Nature core:

"Utilize scientific vocabulary, data, or principles to explain natural phenomena"

ELO from GE philosophy:

Intellectual and Practical Skills, including

- Inquiry and analysis
- Critical and creative thinking
- Written and oral communication
- Quantitative literacy
- Information literacy
- Teamwork and problem solving

Discussion question

What is critical thinking?

Critical thinking - the intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action

Critical thinking skills

1. Posing probing relevant questions
2. Awareness of gaps in knowledge
3. Seeking out relevant information
4. Checking evidence for reliability
5. Distinguishing between observation, inference, and conjecture
6. Drawing inferences from evidence
7. Not drawing inferences that are not supported
8. Probing for assumptions
9. Consideration of other points of view
10. Fair-mindedness and open-mindedness
11. Careful definition of terms
12. Hypothetico-deductive reasoning (posing “what ifs”)
13. Use of both inductive and deductive reasoning
14. Testing reasoning for self-consistency
15. Intellectual confidence, self-reliance, and humility
16. Awareness of your own thinking processes

REAL Explanations

R Rules-explicit statement of logic (e.g. “because”, “therefore”)

E Evidence-facts (e.g. experimental data, info from research)

A Answer-explicitly stated answer (e.g. thesis statement)

L Limitations-conditions that restrict conclusions (e.g. assumptions, uncertainty in evidence, conditions on rules)

Use the REAL explanations framework to analyze the following question and answer.

Q: If a sign says “Speed limit 35 mph”, how fast am I allowed to drive?

A: Speed limits are the maximum allowed speed. Therefore, assuming your speedometer is accurate, you should drive so that your speedometer does not read more than 35 mph.

Rule:
Evidence:
Answer:
Limitation:

Use the REAL explanations framework to analyze the following question and answer.

Q: If a sign says “Speed limit 35 mph”, how fast am I allowed to drive?

A: Speed limits are the maximum allowed speed. Therefore, assuming your speedometer is accurate, you should drive so that your speedometer does not read more than 35 mph.

Rule: Speed limits are the maximum allowed speed
Evidence: Speed limit is 35 mph
Answer: 35 mph
Limitation: Assuming your speedometer is accurate

Use the REAL explanations framework to analyze the following question and answer.

Q: Why did Border's bookstore go bankrupt?

A: The bankruptcy of Border's bookstores was caused by the success of Amazon's Kindle.

Rule:
Evidence:
Answer:
Limitation:

Use the REAL explanations framework to analyze the following question and answer.

Q: Why did Border's bookstore go bankrupt?

A: The bankruptcy of Border's bookstores was caused by the success of Amazon's Kindle.

Rule: Missing
Evidence: Border's went bankrupt
Answer: Success of Amazon's Kindle
Limitation: Missing

Use the REAL explanations framework to analyze the following question and answer.

Q: Who wrecked the snowplow?

A: Harold Simpson wrecked it.

Rule:
Evidence:
Answer:
Limitation:

Use the REAL explanations framework to analyze the following question and answer.

Q: Who wrecked the snowplow?

A: Harold Simpson wrecked it.

Rule: None
Evidence: None
Answer: Harold Simpson
Limitation: None

Advantages of REAL framework

1. Makes expectations explicit
2. Requires critical thinking
3. Intro exercise is metacognitive
4. Trains students in necessary skills
5. Gives shared vocabulary for assessment/feedback
6. Student work improves

Before/After example

These examples are from the same student's homework before and after the REAL explanations exercise.

Before:
Porphyry experienced a two-stage cooling process. It initially cooled slowly deeper in the earth and then cooled much faster at the surface.

After:
I would expect the river to be the fastest in the spring because the river is fuller in the spring. During December and January the temperature is the coldest. The snow is being formed in the mountains. During February there is the most rain, causing added water to the river. Then as March and April come around the temperature gets warmer and the snow begins to melt, filling the river with even more water. Around that time is when the river will be going the fastest through Azusa.

Testing & Grading

0^{th} law of education:

If you don't grade for it, students won't do it.

Corollary to 0^{th} law:

Be careful what you test for, you just might get it.

- Tests and homework should be aligned to course goals.

Example test questions

From Earth Science textbook test bank:

The force that generates wind is _____.
(a) Coriolis force
(b) Gravity force
(c) Centrifugal force
(d) Pressure gradient force

My version:

Suppose that you have graduated and moved to a nice apartment in Santa Monica near the beach. You enjoy taking walks on the beach, but are often annoyed by the wind as you walk. You decide to arrange your daily schedule so that you can take a walk when the wind is likely to be calmest. What time of day should you plan your walk?

Test design principles

1. Not simple factual recall
2. Not memorizable
3. Avoid jargon
4. Avoid multiple choice (or use explained multiple choice)

5. Practice test skills in class
6. Ramp question difficulty
7. Trade coverage for depth
8. Provide data to analyze
9. Phrase as open-ended questions
10. Put in real world context

Test question redesign exercise

The following is a possible test question from a physical science textbook. Rewrite this question to make it consistent with at least two of the test design principles.

> If a submerged object displaces an amount of liquid with a weight less than its own, when the object is released, it will
> (a) sink
> (b) remain submerged in equilibrium.
> (c) float
> (d) pop out of the surface

Grading options

Option #1: Multiple choice with explanations

- Grade for correct answer and correctness/thoroughness of explanation

Option #2: Two scores for explanation structure and correctness

- Structure points for each piece of REAL explanation

Option #2: Partial credit points for each logical step of explained answer

Closing thoughts

- REAL framework identifies elements of good explanations
- REAL scaffolds for students
- Requiring REAL raises expectations & performance for student work

- Don’t settle for the default
- Design graded tasks to match course goals
- Train for skills needed to succeed on course goals