CHANGING BIOLOGY COURSES TO FOSTER CRITICAL THINKING
Using evolution to teach critical thinking in science
(and as a model for other topics in biology)
Conversations, Reflections & Resources
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FRAMING QUESTIONS
Why Is Critical Thinking So Hard For Students To Learn? Why Does CT Matter?
Can We Foster CT Better Without Sacrificing Rigor?

Opening Conversation: Biology at SCC

Are Major Skills Outcomes Specified?
Extent of Outcomes-Driven Course & Curriculum Design?
Major Skill Outcomes → Pedagogies to be Used → Content Choices
[Contrast to: Content-Driven Course & Curriculum Design]
Explicit Frameworks Used for Understanding Student Difficulties?
Misconceptions & Alternative Conceptions?
Piaget (concrete to formal or post-formal) or "hypothetical-deductive"?
Constructivism?
Perry or Baxter Magolda (Etc): Intellectual or Holistic Development or Self-Authorship
SoTL Driven Pedagogy or Tradition Driven & Pedagogy?
Learning Focused Pedagogies (v Teacher Performance Pedagogy)?
“Clickers” or equivalents? [Mazur: Peer Instruction]
Just-in-Time-Teaching. JiTT?
Process Oriented Guided Inquiry Learning (POGIL)?
Concept Mapping? Sem-Net?
Learning Cycles?
Supplemental Instruction?
Learning Communities? Strong or Weak?
Assessments of Learning Gains?
Formative: Classroom Assessment Techniques? Others?
Summative: Pre & Post Tests? Others?
Cognitive Development & Critical Thinking
[Nuclear Power as an Example]

SGT FRIDAY
Facts
One Authority Has The Truth
[Nuclear Power Either a) Is Really Safe or b) Should Be Totally Banned]
| <----- UNCERTAINTY |

BASKIN ROBBINS
Opinions
Each Person's Views are Right For Her
[Nuclear Power: Why Argue? Just Respect Each Other!]
| <----- COMPARISONS & CRITERIA |

TEACHERS' GAMES
Making Arguments
Let's Really Understand Everyone's Arguments & Frameworks
[Nuclear Power: Environmentalists Argue That …. Whereas …]
| <----- CONSEQUENCES & VALUES FRAME |

OWNED GAMES
Contextual Decisions
Some Frameworks / Combinations Are
More Appropriate For Particular Contexts
[Nuclear Power: Safe Enough for Some Uses (Submarines)
But Not for Others (Power-Plants in Urban Areas) Because …]

Evolution: Our Truth;
Any Opinion, if you like it;
Teachers' Games & Preachers' Games;
C, E, or Both?

• Wm. G. Perry, Jr. 1970. Forms of Intellectual and Ethical Development in the College Years.
Holt, Rinehart and Winston.
• M. Baxter Magolda. 2001. Making Their Own Way: Narratives for Transforming Higher Education to Promote
Self-Development. Stylus.
PHASE 1: INTERACTIVE LECTURES WITH CATS

A. Set up Alternatives To Compare [Critical thinking is usually about comparisons.]

Example: Age of Earth / Universe (Alternatives From Darwin's Time):
2. Geologists: Several Hundred Million Years--From Rates Of Geological Processes

B. Introduce Key Way To Compare: Fair Tests [Concept]
1. New Kind of Evidence-Not Based On Same Kind Of Evidence As Any Alternative Being Compared
2. Not Biased: Could Have Supported Any Of The Alternatives

B1. Use Simple CATs to Encourage & Check Understanding

FOR EXAMS: Be Prepared To Explain Your Answers To Any Of The Multiple Choice Questions
1. Scientists think that a fair test is one that:
a) could have shown any of the alternatives to be either probably correct or probably wrong.
b) is based on a line of data or reasoning independent of those on which each alternative is based.
c) yields a lot of data
d) contradicts popular ideas
e) supports their own preferred answers
f) none of the above, all of the above, or only two of the above

C. Develop Series Of Fair Tests

Example: [For Age] Cosmic Yardsticks: Light Takes Time To Travel; Out In Space = Back In Time
Observed Size Yields Minimum Age Of Universe. Why?

D. Introduce Additional Criteria, Illustrate & Do CATs

Example: A Scientific Theory Is Better Science [7 Basic Scientific Criteria]:
1. If It Better Matches The Data From A Fair Test
2. If It Is Confirmed By Multiple Independent Fair Tests
   Age: Cosmic Yardsticks, Radioactive Clocks & Many More
3. If Initially Conflicting Data Can Be Shown To Agree
   = Explanation of Anomalies: Age: Radioactivity & Kelvin's Estimates
4. If There Are No Conflicting Lines Of Scientific Evidence
5. If The Fair Test That Supports It Is Particularly Strong
   Age: Radioactive Clocks: Internal Checks Agree
   & Larger Causal Framework Predicts Must Work

….. X. CREATION, EVOLUTION OR BOTH?

1. Spectrum from Young Earth to Theistic and Non-Theistic Evolution.
2. Rusty Hand-grenade: Basic Decision Theory.

3. Benefits of evolution and costs of excessive skepticism:
   How is Microevolution important to medical science?
   How is Phylogenetics important to medical science?
   How is Macroevolution is important to medical science?
   How is Microevolution important to industry?
   How is Microevolution important to agriculture?
   How is Macroevolution important to agriculture?
   Theme: Moral responsibility for consequences of one's beliefs & actions


EXERCISES
[From or modified from: “Social Sciences Piagetian Inventory,” “Group Assessment of Logical Thinking.” & Lawson’s papers]

1. Choose four boys names and four girls names. How many dance pairs can be formed?
[Answer key usually assumes heterosexuality but options would be easy.]

2. Given drawings of four groups of fish: 3 big with broad stripes, 9 small with broad stripes, 4 big with narrow stripes and 12 small with narrow stripes:

   YES or NO: Is there a relationship between size of fish and width of stripe?
   [i.e. Is one size of fish more likely than the other to have a certain stripe type?]

   WHY (Pick best ONE):
   • Big and small fish can have either type of stripe.
   • 3/7 of big fish and 9/21 of small fish have narrow stripes.
   • 7 fish are big and 21 are small.
   • Not all big fish have wide stripes and not all small fish have narrow stripes.
   • 12/28 of the fish have wide stripes and 16/28 of the fish have narrow stripes.

3 You have a number of blocks that are one-inch cubes. These will just fill a box that is 3 inches wide, 4 inches long and 5 inches high. They would also just fill a box that is 2 inches wide, 3 inches long and ____ inches high.

4. Pendulums: See the drawings of three strings hanging from a bar [figure not here]. The three strings have metal weights attached to their ends. String 1 and String 3 are the same length. String 2 is shorter. A 10-unit weight is attached to the end of String 1. A 10-unit weight is also attached to the end of String 2. A 5-unit weight is attached to the end of String 3. The strings (and attached weights) can be swung back and forth and the time it takes to make a swing can be timed. Suppose you want to find out whether the length of the string has an effect on the time it takes to swing back and forth.

Which strings would you use to find out:
(A) only one string, (B) all three strings, (C) 2 and 3, (D) 1 and 3, (E) 1 and 2.

Because (A) you must use the longest strings, (B) you must compare strings with both light and heavy weights, (C) only the lengths differ, (D) to make all possible comparisons, (E) the weights differ.


"The concrete operational student will not see the … reasoning inherent in the formal strategy and will either avoid using it because it doesn’t make sense or will memorize the algorithm which the instructor insists that he learn, and apply (or misapply) the algorithm blindly.” (p 166)

“Piaget argues that everyone reverts to concrete operational or pre-operational thought whenever they encounter a new area. … How many times have you listened to someone explain a new idea, been confused, and asked “Can you give me an example?”

Because we are at the point that concrete experience in chemistry is superfluous, we tend to forget that it was not always so and in our rush to "cover the material,” we omit the very kind of experiences that can make our subject meaningful to beginning students. One additional point about the value of using concrete operational reasoning and concrete referents in developing new ideas should be made: the point is that, by doing so, we may be able to get concrete operational students to believe that a formal procedure is correct even though they do not understand why it is correct.” (p 167)
**PIAGET:** From “Concrete Operations” to “Formal Operations” (& maybe Post-Formal)

**Stories:** (1) Three pieces of cake. (2) Black and white and wooden beads. (Robert Kegan)

**Formal Operations Tasks Include:** Area and volume as unit squares and unit cubes; Systematic combinations (dance partners; experimental controls); Correlational (fish stripes); "Other things equal" (pendulum). "Hypothetica"I--Cannot be observed directly (density)

Piaget choose the name "formal operational" for his highest state of thought development. . . . The terms "empirical-deductive" (ED) and "hypothetical-deductive" (HD) seem to better capture the key difference [between child-like and adult-like thinking].

*Lawson (1995, p.102) [Quoted in Hake 2005]*

**Bruner's recharacterization** of the "stages" as "multiple (and parallel) ways of knowing"


R. R. Hake. 9/5/2005. Has Piaget Gone Down For the Long Count? POD@listserv.nd.edu [Search archives]


- Using **course final grade** as the dependent variable with post-test scores for reasoning and self-efficacy estimates and ACT/SAT: Post-test reasoning was the strongest predictor of final course grade, accounting for 32% of the variance; ACT/SAT accounted for an additional 8%; Post-test self-efficacy accounted for a further 1%.
- Using **final exam grade** as the dependent variable with post-test scores for reasoning and self-efficacy estimates and ACT/SAT, Post-test reasoning accounted for 35% of the variance; ACT/SAT accounted for an additional 4%; Post-test self-efficacy accounted for a further 2%.
- Individually Pearson correlation coefficients with course final grade were significant (p<0.01 two-tailed) for Pre-test Reasoning (R = 0.45), Post-test Reasoning (0.55) and ACT/SAT (0.52), and, less strongly, Post-test Self-Efficacy (0.24). ACT/SAT was most strongly correlated with Pre-test Reasoning (0.55) Post-test Reasoning (0.41)
- Students tended to overestimate their abilities to carry out the tasks.

**Lawson (1995, p.102) [Quoted in Hake 2005]**

PROCEDURES AND STRATEGIES THAT IMPEL STUDENTS TOWARD FORMAL OPERATIONAL THOUGHT AND DRAW THEM THROUGH ITERATIONS THAT LEAD TO “EQUILIBRATION” OF THE NEW INTELLECTUAL LEVEL ATTAINED

Excerpted and paraphrased from:

1. Exploratory activity and question asking prior to concept formation and model building.
   a) Explore balancing prior to induction of quantitative relationship.
   b) Explore how to light flashlight bulb with 1.5 V cells prior to formations of related concepts.
   c) Naked eye astronomy prior to phases of moon and geo & helio centric models of solar system.
      • Use English to form questions before invoking technical terminology (not yet understood)
      • Opportunity to distinguish observation and inference.

2. Idea first and name afterwards.
   a) Count unit squares for an irregular shape prior to “area” & unit cubes prior to “volume.”
   b) Observe changes in electrical systems prior to “circuit.”
   c) Developing evidence and examining phenomena from which one infers discreteness of matter before introducing terms “atoms” and “molecules.”
      • Idea first and name afterwards underlies the idea that words acquire meaning only through elements of shared experience. Students think that if you know the “name” you understand it. Need practice making intelligible operational definitions.

3. Translating words into symbols and symbols into words. [Symbols here include graphs.]

4. How do we know ...? Why do we believe ...? & What is the evidence for ...?
   a) Why do we believe that the earth revolves around the sun?
   b) Why do we believe that there are only two varieties of electrical charge?
   c) In what sense and on what evidence do we view light as a waved phenomenon?
      • Most students accept these things on faith. They have almost never examined the evidence or articulated in their own words the reasons we hold these views. Before submerging them further in the end results, it is essential to lead them to an understanding of some of our most fundamental and far-reaching ideas.
      • “Eventually it does become necessary to take some end results of scientific inquiry on faith; we cannot develop extensive evidence in every area we wish to study or interrelate.” The students, however, have taken everything on faith.

5. Inferences drawn from models.
   a) What would things be like on earth if the ecliptic coincided with the celestial equator?
   b) Is it possible to discriminate between the geo and helio-centric models of the solar system on the basis on naked eye observations? (Many students have great difficulty understanding that it is impossible to discriminate between two models that equally well account for the available observations. They expect to be able to “prove” the one they “know” to be correct.)
      • “It is essential that students have time to express the requisite lines of reasoning in their own words, drawing as much as possible in their own observations and experiences. Telling them the correct answers in lucid lectures, explanations or text presentations is futile. This is what has been done before and it has left no trace on the students’ intellects.” (p 835)

[Continued on next page]
6. **Backwards science; forwards science.**

a) **Student:** If the moon and sun are on opposite sides of the earth when we see a full moon, why is the moon no eclipsed each time by the shadow of the earth? **Teacher:** Because the moon, earth and sun are usually not in a straight line. [= backwards science]

- A *because* answer to a *why* question carries for the student a clear implication that the scientist know an *a priori* reason for the “because.” “**Answers of this kind strongly inhibit the progress of the student toward formal operations.**” What is necessary is a prompt reversal of the initial sequence. A *much more effective teacher response is:* “It is an observed fact that the full moon is not eclipsed every month. What can we infer from this observation about the character of the moon-earth-sun alignment?”

7. **Interpretation of the results of multiplication and division in specific contexts.**

- Many students who are still essentially concrete operational do not interpret multiplication as a form of addition or counting in contexts where such an interpretation is appropriate. For example, *they do not recognize the calculation of length X width for a rectangular surface as a short way of counting the unit squares. It is no use telling them or explaining, however lucidly, that the operation counts the unit squares; they have been told this before and it did not register.* The interpretation must be extracted from them in their own words by a sequence of questioning, and they must be led to give the explanation on tests, as well as being led to give the parallel interpretation in the case of the calculation of the volume of a parallelepiped.

- Students who are somewhat further along … frequently run into formidable obstacles in the interpretation of division. They have never interpreted division as calculating how much of the numerator is in one chunk of whatever is in he denominator. Example: “We have given the name density to the number obtained when we divide the mass (M grams) of an object by its volume (V cubic centimeters). How do you interpret the number M/V? What does it mean in simple terms?” Many students will bog down completely or they will mutter something meaningless like “mass per volume.” They can be led to understand that this is grams in one cubic centimeter by going first to price per ounce and then ounces per dollar. **Consolidation requires interpreting fractions in several contexts. Make them reword any sentence containing ‘per.’** [Worth reading in full.]

**Arithmetical reasoning involving division.**

a) The efforts in section 7 are only the first step. Then try “We have 800 g of material having a density of 2.3 g/cm³. What must be the volume occupied?” The goal is to lead the students to see that 2.3 g is the amount in 1 cm³.

b) Once they have that ask: “We have a block consisting of 1000 g of a material with a density of 2.3 g/cm³. Suppose we add 800 g of the same material to the block. By how much have we increased the volume of the block?”

c) **Consolidation requires interpreting complex divisions in several contexts.**

**Arons gives extended student-by-student evidence that these procedures produce advances in reasoning and understanding.**
EXERCISE [From Lawson et al. 2007]:

Concrete Matching Questions

1. Suppose you find an animal skull that is very narrow and streamlined. This makes you think that the animal lived in the water. If this hypothesis is correct, where should its backbone attach to the skull? (A) Directly below the skull. (B) Directly behind the skull (correct answer). (C) At the back of the skull but pointing down at about a 45 degree angle. (D) At the top of the skull.

3. Suppose you collect 250 shells of a single snail species from the ocean. What would you expect a graph of their lengths versus frequency to look like? (A) bell-shaped (correct answer); (B) positive linear (line from the lower left to upper right); (C) negative linear (line from the upper left to lower right); (D) flat E. bimodal.

Formal Matching Questions

1. An experimenter wanted to test mealworms’ response to differences in light and moisture. To do so he set up four boxes. He used lamps for light and placed watered pieces of paper in the boxes for moisture. In the middle of each box he placed 20 mealworms. One day later he counted the mealworms that had crawled to the ends of the boxes. Which of the following is an independent variable being tested? (A) amount of light (correct answer); (B) type of light; (C) age of mealworms; (D) movement of mealworms; (E) number of mealworms.

3. Which of the following best tests the hypothesis that grass grows better on the north slope of ‘‘A’’ Mountain than the south slope because the soil on the north slope is wetter in the spring? (A) Measure the amount of soil moisture on both slopes in the spring; (B) plant identical grass seed on both slopes in the spring and monitor resulting growth; (C) water the soil on the south slope in the spring so that it has the same amount of moisture as the north slope (correct answer); (D) conduct a controlled experiment in the lab in which grass seed is planted in two boxes of soil and only the amount of water in the boxes varies.

Postformal Matching Questions

1. When graphed, within-species variation often shows a normal distribution. To test the hypothesis that a specific normal distribution has a genetic basis, one could: (A) examine the DNA of organism with different characteristics; (B) observe the organisms in their natural habitat over several generations; (C) use a Punnett square to determine the frequency of gene combinations; (D) mate some specimens that have different characteristics and observe their offspring. (correct answer); (E) observe the parental and offspring genotypes of several different organisms.

2. Can trees communicate with each other using chemicals in the air? For example, perhaps when a tree’s leaves are attacked by insects, the leaves release a chemical into the air. When the leaves of nearby trees take in the chemical, they then produce another chemical that is poisonous to the attacking insects, so they are protected from attack. How could this plant communication hypothesis be best tested? (A) Place attacking insects on several trees and place a chemical detector nearby to detect and record any chemicals that are produced. (B) As soon as a tree is attacked, spray the insects to kill them. If the trees can communicate, then nearby trees should not produce the poisonous chemical. (C) Place attacking insects on several trees and then analyze the leaves of nearby trees to see if they contain poisonous chemicals. (D) Place attacking insects on two trees in two locations. Then bag one tree in plastic and check for poisonous chemicals in nearby trees (correct answer).
In-Class Question Practice: Multiple choice (etc) individually, Pairs, Debrief


Fast-Plants. e.g. Gravitropism Revisited - (36K PDF file). Pairs or individual. OK in large class. Film can gravitropism chamber out of a film can, tape, paper towels & a small pipette. Observe the plant's response to gravity. http://www.fastplants.org/activities.physiology.php Many more activities at: http://www.fastplants.org/activities.php

Molecular biology: “Pipe-Cleaner Models” made in class by the students from various kits. Zip-Lock bags: pipe-cleaners, beads, tape polyethylene strips etc. This one 25 cents (in 1996 $$):

Figure From: Malacinski, G. M., and P. W. Zell. 1996. Manipulating the "invisible": Learning molecular biology using inexpensive models. Amer. Biol. Teacher: 58: 428-432. “Simply stated, concrete thinkers depend primarily on their senses to learn. Although concrete thinkers can think logically, their logic is limited to immediate experience with things they can see and manipulate directly. Their reasoning is based on "real" rather than "abstract" possibilities. Since abstract concepts are not amenable to sensing, students who are not formal in their thought patterns have great difficulty mentally representing the abstract and complex operations of molecular biology.”

Molecules & Evolution: Sequences, Matrix, Ordered-Matrix; Tree; Node-Rotations, Rates Structured Worksheets. Groups of 2 or 3. Any class size.

Graphs <= Equations <= Concepts: Unmasking “Hidden Transformations.” Any class size. Start with \( N_t = N_0 \) for all \( t \). Individuals, then pairs, then whole class discussion.
**Case Study Teaching in Science, National Center for.** SUNY-Buffalo (Clyde Herreid)
[How to and many cases.] [http://ublib.buffalo.edu/libraries/projects/cases/case.html](http://ublib.buffalo.edu/libraries/projects/cases/case.html)
Don’t miss the links to other case studies sites: [http://ublib.buffalo.edu/libraries/projects/cases/webcase.htm](http://ublib.buffalo.edu/libraries/projects/cases/webcase.htm)

**Investigative Cases at BioQUEST Curriculum Consortium.**

**Research-Like Inquiry Cases: “Problem-Spaces” at BEDROCK Bioinformatics Education Project**
[http://bioquest.org/bedrock/](http://bioquest.org/bedrock/) The project is built on the premise that an evolutionary framework can be used to link bioinformatics analyses with many disciplinary research questions throughout the undergraduate biology curriculum. The site emphasizes an inquiry approach, allowing students to learn through engagement in research activities. It provides both data sets and a set of analytical tools. **“Problem Spaces” include:** HIV sequence evolution, Galápagos finch classification, Whale origins (WHIPPO), Chimpanzee conservation, Epidemiology of the West Nile virus, and Protein structure and function using Trp-cage. (Also: Desiccation Tolerance, Enolase, Prion & Tamarix)


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![Figure 5. Degree of direct student involvement in various teaching methods](image)
TWO FURTHER COMPLEMENTARY FRAMEWORKS

MISCONCEPTIONS AND ALTERNATIVE CONCEPTIONS


Great videos showing persistent misconceptions:

Harvard-Smithsonian Center for Astrophysics (Distributed by Annenberg Media).

PU: “With its famous opening scene at a Harvard graduation, this classic of education research brings into sharp focus the dilemma facing all educators: Why don’t even the brightest students truly grasp basic science concepts?”

MOO: “Why is it that students can graduate from MIT and Harvard, yet not know how to solve a simple third-grade problem in science: lighting a light bulb with a battery and wire? Beginning with this startling fact, this program systematically explores many of the assumptions that we hold about learning to show that education is based on a series of myths…. the program takes a hard look at why teaching fails…”

USE: Video on Demand links to see these free. [Macs: Use Safari, Firefox doesn’t work.]

ONTLOGICAL REFORMULATION


Ontological Shifts: Many “misconceptions” in science are very resistant to instruction. Many such problems hinge on students trying to understand “processes” as “substances” (e.g. heat transfer, light, electric current, force, natural selection, and economic phenomena such as supply and demand, and the stock market). Even within “process,” causal and emergent processes are ontologically distinct: “In causal processes, the process itself can be explained by identifiable actions, with temporal and spatial contiguity, and with an identifiable beginning and ending. For example, a baseball game is a causal event. There is a beginning and an ending, with temporal and spatial sequence. A team’s wins or losses can be attributed to certain causal actions, such as how well the pitcher pitches. An emergent kind of process, on the other hand, does not have any of these properties. Instead, an emergent process is caused by the collective aggregation of multiple, independent causal events. For example, birds flocking in a V-formation may look like a causal event (in that the lead bird shows the others where to fly). It is actually an emergent process, in that each bird tends to fly in a location that has the least resistance and drag. If each bird independently follows such a simple rule, it will result in the flock flying in a V-formation.” [From: http://www.pitt.edu/~chi]

Providing students with explicit training in understanding one set of examples as emergent processes has been shown to enable many of them to spontaneously understand other concepts as processes. (Chi, Slotta and their colleagues.)
GREAT SOURCES FOR INTERACTIVE ENGAGEMENT/ACTIVE LEARNING

All online (except the books)


Just-in-Time-Teaching. “JiTT is a teaching and learning strategy based on the interaction between web-based study assignments and an active learner classroom. Students respond electronically to carefully constructed web-based assignments which are due shortly before class, and the instructor reads the student submissions "just in-time" to adjust the classroom lesson to suit the students' needs…. we are aware of approximately 300 faculty in 25 disciplines at approximately 100 institutions … who have adopted the JiTT strategy.”

http://webphysics.iupui.edu/jitt/jitt.html

Mazur’s Peer Instruction [Brief lecture segments interspersed with carefully structured discussion.]

Process Oriented Guided Inquiry Learning (POGIL). A POGIL classroom or lab consists of any number of students working in small groups on specially designed guided inquiry materials. These materials supply students with data or information followed by leading questions designed to guide them toward formulation of their own valid conclusions - essentially a recapitulation of the scientific method. The instructor serves as facilitator, observing and periodically addressing individual and classroom-wide needs. POGIL is based on research indicating that a) teaching by telling does not work for most students, b) students who are part of an interactive community are more likely to be successful, and c) knowledge is personal; students enjoy themselves more and develop greater ownership over the material when they are given an opportunity to construct their own understanding.

http://www.pogil.org/info/introduction.php


Problem Based Learning Clearing House. University of Delaware. https://chico.nss.udel.edu/Pbl/
See also list of sites: http://www.udel.edu/pbl/others.html

GREAT SOURCES: OUTCOMES-FOCUSED COURSE AND CURRICULUM DESIGN


YOU CAN USE WRITING, EVEN IN LARGE CLASSES, WITHOUT GRADING TROUBLES

Calibrated Peer Review (CPR)™ “is a Web-based program that enables frequent writing assignments even in large classes with limited instructional resources. In fact, CPR can reduce the time an instructor now spends reading and assessing student writing.” Developed for science with $ from NSF & Howard Hughes. http://cpr.molsci.ucla.edu/


IS IT WORKING? ASSESS AND DOCUMENT WHAT IS HAPPENING IN YOUR CLASS


Great Starting Sites: : Assessment Resources, National Resource Center on the First-Year Experience and Students in Transition, University of South Carolina. Includes a Searchable Database of Assessment Instruments, a list of Learning Styles Assessment Instruments, Invited Essays on key topics and programs, a List-serve with Searchable Archives AND Resources for First, Second and Senior Year Courses including primers, syllabi and more http://www.sc.edu/fye/resources/index.html
COLLEGE SCIENCE TEACHING

FIVE GREAT STARTS


Science Education Resource Center (SERC) http://serc.carleton.edu/index.html Best comprehensive site.

SOCIETY FOR COLLEGE SCIENCE TEACHERS [National Science Teachers Association] NSTA Press.

Descriptions and sales at: http://www.nsta.org/store/


KEY OTHER ITEMS:


U.S. NATIONAL ACADEMY OF SCIENCE The NAS is trying hard to help faculty understand the evidence and change how we teach! Entire text of each book can be read FREE online by using “Scan” option. [Earlier titles, too]

