Day 1 Handouts:

1) Bloom’s taxonomy
2) Learning goal checklist
3) Course-scale goal slide
4) Tactics
5) Question Goals

Are your students learning the main concepts? Defining learning goals and assessing as you go.

Carl Wieman

Value of explicit learning goals:

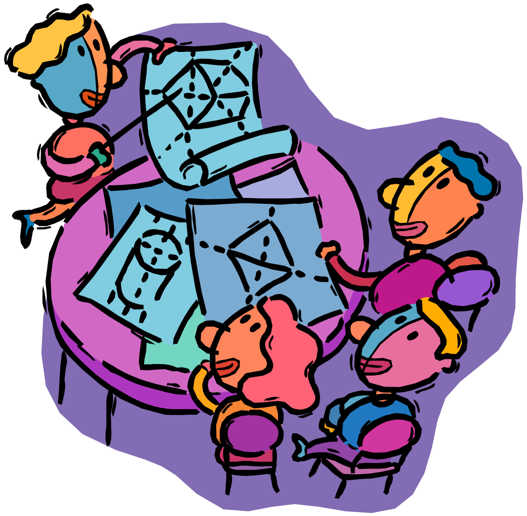
1) better define and guide what you want to teach.
2) define for students what they should be learning (and why).
3) essential for measuring what students are learning -- to guide improvement of instruction

Plan of attack

Wk 1: Developing and using topic and lecture learning goals
Developing questions to assess learning goals

Wk 2: More on assessing learning goals.
Examining broader (course-scale) and longer term goals, better assessment through homework and exams

Have found no substitute for discussion with peers and iteration.
⇒ general and small group discussion and revisions.



Explicit learning goals

- Basic definition: **What should students be able to do after completing course?**
  (How general attitudes or thinking are changed by course?)

- Requirement of a learning goal: Must be measurable
  $\Rightarrow$ *assessment and goals tightly linked*

- Wide range of possible goals:
  From memorizing terminology to
  → complex problem solving skills
  → transferring ideas to new contexts
  → thinking like a scientist
  (Reflection of what you want students to learn and at what level)

Syllabus/Topic list Vs. Learning Goals

Familiar

... good place to start

→expand into learning goals.

Syllabus/ Topic List

- Material covered (and time spent)

Learning goals:

Outcome and student oriented:

- Identifies what students will be able to do as a result of learning

- Defines what students are expected to learn

From Syllabus/Topic list To Learning Goals

Familiar … good place to start … expand this into learning goals

<u>Learning goals:</u>

Course-scale learning goals
(~5 to 10 per course)

Syllabus/ Topic List → Topic-scale learning goals
(~2-5 per topic)

★ Lecture-scale learning goals
(~2-3 per class period)
(~learning objectives)

Consistency, Alignment

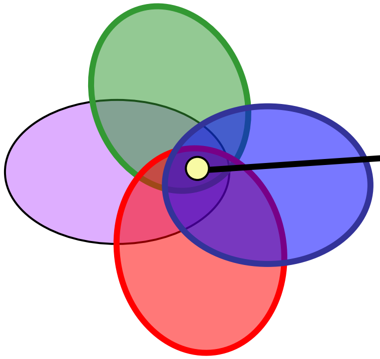
Course-scale learning goals (5-10)

CONTENT

SKILLS

HABITS OF MIND

AFFECTIVE & BELIEFS



One Lecture-scale Learning Goal could touch upon 3 course-level goals

Course-scale learning goals

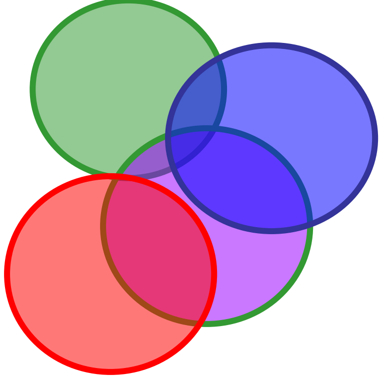
Recognize that the behavior of the world around you is not magical and mysterious, but rather can be understood and predicted using certain fundamental principles.

Understand the properties and motion of electric charges and use this knowledge to predict and explain various aspects of electricity.

Lecture-scale learning goals

Be able to design a fluorescent light bulb and to explain and justify the requirements on the various basic components.

Course-scale learning goals (5-10)



CONTENT: Be able to analyze, explain, and predict the motion of objects in the world around you

SKILLS: Cognitive/Process skills:
Reasoning, Problem Solving, Evaluating, Critiquing…
Technical skills:
Computer skills (debugging, software specific, …

HABITS OF MIND: Think like a ________:
Use alternative representations; Compare and contrast; Reflect; Strategize, justify, and plan;

AFFECTIVE: Appreciate, Enjoy, Value,
(e.g. Recognize that the behavior of the world around you is not magical and mysterious, but rather can be understood and predicted using certain fundamental principles.)

BELIEFS: About nature of learning and doing _______:
(e.g. Believe that learning and doing physics is more about reasoning and making sense, not memorizing.)

Bloom's Taxonomy of the Cognitive Domain
(Levels of Learning)

1. Factual Knowledge: remember and recall factual information

2. Comprehension: demonstrate understanding of ideas, concepts

3. Application: apply comprehension to unfamiliar situations

4. Analysis: break down concepts into parts

5. Synthesis: transform, combine ideas to create something new

6. Evaluation: think critically about and defend a position

Bloom's Taxonomy of the Cognitive Domain (Levels of Learning)

1. Factual Knowledge: remember and recall factual information
   Define, List, State, Label, Name, Describe
2. Comprehension: demonstrate understanding of ideas, concepts
   Describe, Explain, Summarize, Interpret, Illustrate
3. Application: apply comprehension to unfamiliar situations
   Apply, Demonstrate, Use, Compute, Solve, Predict, Construct, Modify
4. Analysis: break down concepts into parts
   Compare, Contrast, Categorize, Distinguish, Identify, Infer
5. Synthesis: transform, combine ideas to create something new
   Develop, Create, Propose, Formulate, Design, Invent
6. Evaluation: think critically about and defend a position
   Judge, Appraise, Recommend, Justify, Defend, Criticize, Evaluate

Higher level: Require deeper conceptual understanding

Lecture-scale learning goals (2-3 per class period)
Example: Be able to design a fluorescent light bulb and to explain and justify the requirements on the various basic components.

Check-list for creating **lecture-scale** learning goals:

✓ Is goal expressed in terms of what the student will achieve? Does it identify what students will be able to do after the topic is covered?

✓ Is the Bloom's **level** of the goal aligned with your expectations for students' learning … Is this what students will be able to do if they "understand" the topic at the level you want?

- ✓If you expect reasoning for "why", does it convey that?
- ✓Could you expect a higher level goal?

✓Is it well-defined? Is it clear how you would test achievement?

✓Do chosen verbs have a clear meaning?

✓Is terminology familiar/common? If not, is the terminology a goal?

Not every goal can achieve the following, but if you can express it to address these, that is better:

✓Is it relevant and useful to students? (e.g. connected to their everyday life, or does it represent a useful application of the ideas).

Biology Learning Goal Examples

Human Genetics for non-majors

Course-level learning goal	Specific learning goal
Content: Demonstrate how meiosis leads to diversity in the next generation Skills: Become better problem solvers	Original wording: Understand the rules for inheritance of chromosomes in the process of meiosis.
	Reworded: Predict the probability of generating sperm and egg cells with specific chromosomal makeup. (Blooms level 3), and explain how these cells are produced (Blooms level 2).

Introduction to Molecular and Cell Biology

Original L.G.	Problems
Describe how the process of extracting information from genetic material is regulated at each step of conversion of DNA to RNA to protein.	Low level goal—explicitly encourages students to memorize the steps from DNA to protein

New L.G.	Advantages
Propose two different ways that an abnormal protein could be made in a cell, resulting in disease symptoms.	Higher level goal—encourages student to think about how proteins work, how they are produced, and how they can be altered by mutations in DNA.

What level is this and do you have suggestions for improving ?

- **You should know how to apply Ohm's Law, and be able to calculate V, I, and R for various elements in a variety of circuit configurations.**

{Ohm's law: voltage (V) = current (I) x resistance (R)}

Levels of learning goals

Topic = Provincial Government/Democracy

- **With partner write two specific learning goals:**
  - **1 learning goal at Blooms Level (1 or 2) and decide what level it is.**
  - **1 learning goal at Blooms Level (3-6) and decide what level it is.**

Goals:
To be able to use Bloom's taxonomy to help craft and to identify learning goals at various cognitive levels.
To be able to debate the limitations of relying solely on the verb to define the level.

Next Activity:

Work on your learning goals with your table group

- **Share with each other some of the learning goals (LG) that you have for a class that you teach.**

- **Pick one that you feel could be improved.**

- **Use your white boards to work on revising the LG.**

  - **Compare the current wording of the LG to the guidelines we have provided (identify the "level" of this LG, and whether it is too broad or too narrow).**

  - **Discuss how the LG could be rewritten to better state your true goal.**

Testing achievement of learning goals:

- Formative assessment (Know what students think now (before exam), and fix it!)

- By what methods could you ask a question on one of your lecture-scale learning goals, collect answers, and evaluate it?

Each question sends a message to the students:
3 areas to consider when developing a question

1. **Content Goal: Does the question test an essential aspect of the material?**

2. **Cognitive Goal: How do students use the content to arrive at the answer? What does it mean to learn or "do" this subject?**

3. **Metacognitive Goal: Are students examining their own thinking?**

The Montillation of Traxoline

when assessment goes astray

It is very important that you learn about traxoline. Traxoline is a new form of zionter. It is montilled in Ceristanna. The Ceristannians gristerlate large quantities of fevon and then bracter it to quasel traxoline. Traxoline may well be one of our most lukized snezlaus in the future, because of our zionter lescelidge.

- - - -

Assessment of Understanding

Answer these questions in complete sentences. Be sure to use your best handwriting.

1. *What* is traxoline?
2. *Where* is traxoline montilled?
3. *How* is traxoline quaselled?
4. *Why* is it important to know about traxoline?

[attributed to Judy Lanier]

Each question sends a message to the students:
3 areas to consider when developing a question

1. **Content Goal: Does the question test an essential aspect of the material?** Is it aligned with your learning goal?

Defines students focus … what they think your goals are.

2. **Cognitive Goal: How do students use the content to arrive at the answer? What does it mean to learn or "do" this subject?** What are the cognitive processes involved? Are they comparing and contrasting phenomena, ranking, classifying, or performing a mathematical manipulation?

3. **Metacognitive Goal: Are students examining their own thinking?**

Hidden/implicit

Small (table) group activity:

1) write a question to test learning of one of your goals. What are goals of your question (content, cognitive, metacognitive).

Follow-up discussion of process and of question design.

Avoid rote memorization strategies:

- “Troubleshooting”
  - something changes, what could cause this?
- “redesign”
- “compare and contrast” scenarios

How would implement your question in class? (logistics)

Ideas for implementation:

- Ask question in exam or homework.
- Ask students to write answer to a question on a sheet of paper and turn it in.
- Ask students to write answer on own, then discuss with others, then write a revised answer.
- Ask students to discuss question in groups, write a group answer.
- Ask a multiple choice question and ask students to vote using their hands, colored cards, or clickers.
- Students can answer on their own or discuss in groups.
- Give credit for answering questions but don’t grade.

Clickers, Colored Cards
One Minute Papers (individual or group)
Pretest - Posttest

End day 1.

Homework

1. Try “formative” assessment question in class.

    Next session--discuss how done, logistics, what learned, how might change?

2. Develop 3 or 4 course level goals.

Day 2 Handouts

- Exercise sheet with course/class activities and with example on the back
- FCI content survey
- CLASS survey

Important questions from first session.

1. **Goals that can't be measured?**
Course level goals often too broad to measure directly. Clarified and defined by detailed goals that are measurable.
(If still not measurable, declare attained. ☺)

2. **Goals too specific, limit contexts of application?**
Goal quite specific for given context, but then added goal is "Be able to apply to range of contexts." (With range of interest defined.)

3. If goals are specific, won't they just memorize material?
Probably not as much as if goals not specifically state involve things beyond memorization.
b. Not as easy as might think if use higher level thinking verbs/questions/activities. *(think Montillation of Traxoline)*

alignment-- lecture, homework, exams

Day 2

Any notable experiences from formative assessment?

I. More on question development.
- Different representations
- Question design tactics - Beatty et al

II. Course level learning goals.

What representations are used in your fields?

- Earth and Ocean Sciences

- Computer Science

Could you use alternative representations with your questions?

Concept map in Evolution

Concepts:

Survival of the fittest

Genetic code

Mutations

Speciation

Diversity

Reproduction

Isolation

Differentiation

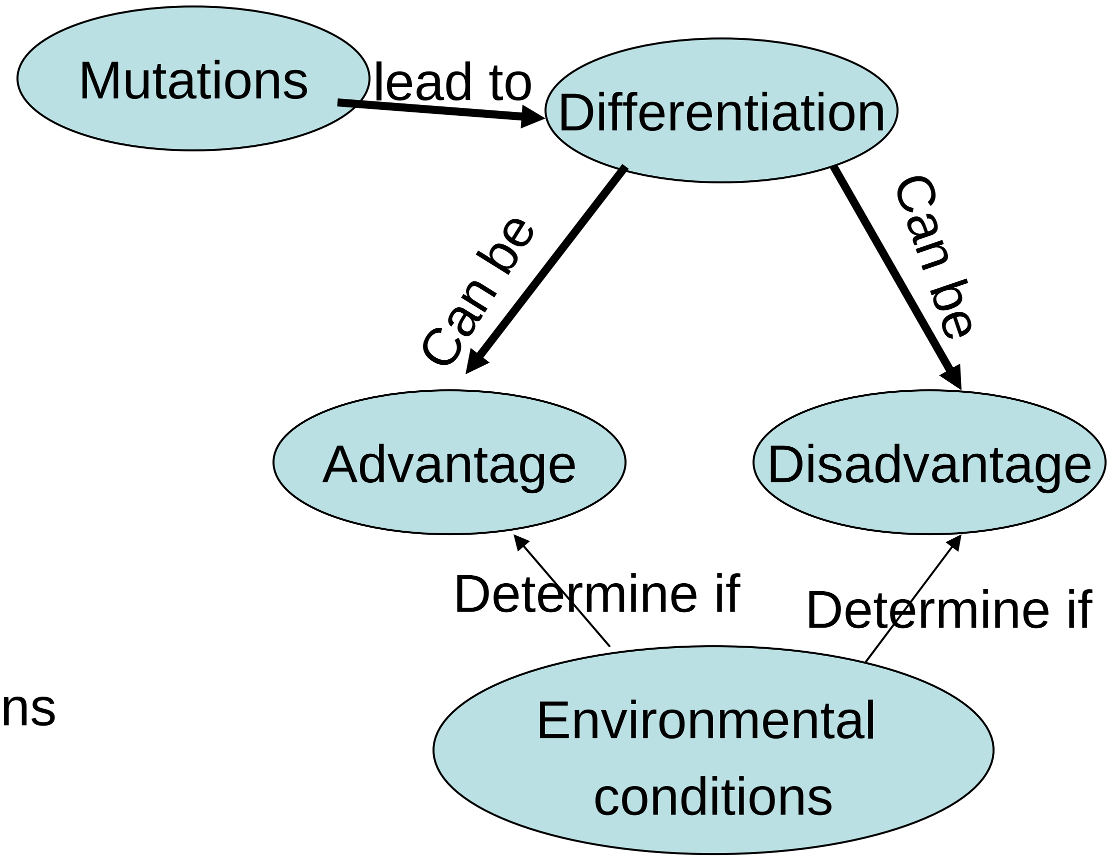
Advantage

Disadvantage

Environmental conditions

Protection

Draw a map inserting terms that link these concepts

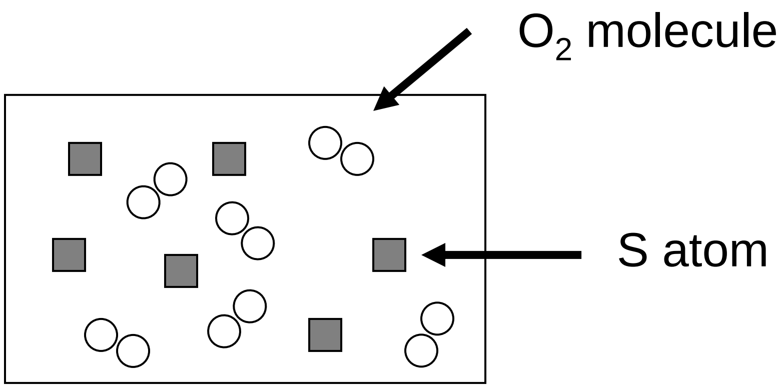


Ex: Revising a Chemistry Question to use representations

If you start with 6 S atoms and 6 O_2 molecules, how many SO_3 molecules can you form given the following reaction?
$2S + 3\ O_2 \rightarrow 2\ SO_3$

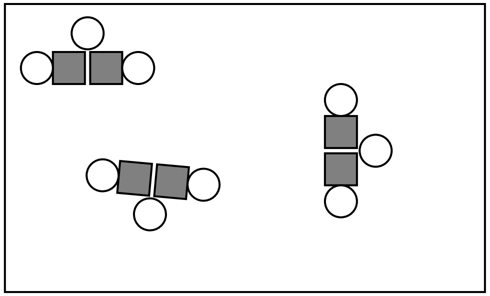
A. 2
B. 3
C. 4
D. 5
E. 6

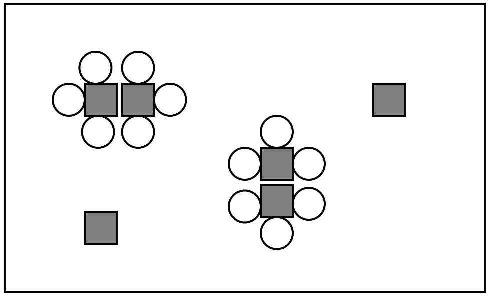
This diagram represents a mixture of S atoms and O_2 molecules in a closed container.

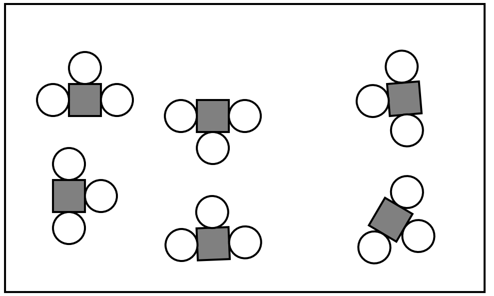


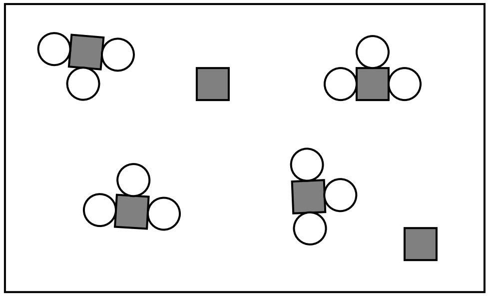
Which diagram shows the results after the mixture reacts as completely as possible according to the equation

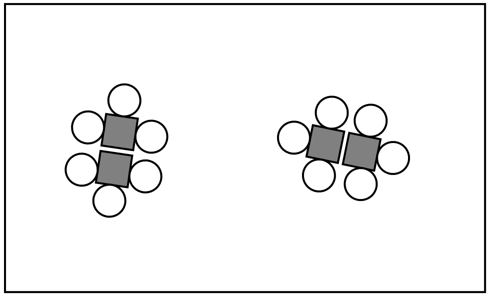
$2S + 3\ O_2 \rightarrow 2\ SO_3$

A.


B.


C.


D.


E.


Question Development:
One question can address multiple types of goals

1. **Content Goal: Does the question test an essential aspect of the material?** Is it aligned with your learning goal?

2. **Cognitive Goal: How do students use the content to arrive at the answer? What does it mean to learn or "do" this subject?** What are the cognitive processes involved? Are they comparing and contrasting phenomena, ranking, classifying, or performing a mathematical manipulation?

3. **Metacognitive Goal: Are students examining their own thinking?**

Question Design Tactics (from Beatty Article)

Tactics for directing attention and raising awareness:

- Remove nonessentials
- Compare and contrast
- Extend the context
- Reuse familiar question situations
- Oops-go-back

Tactics for formative use of response data:

- Answer choices reveal likely difficulties
- Use “none of the above”

Tactics for stimulating cognitive processes:

- Interpret representations
- Compare and contrast
- Extend the context
- Identify a set or subset
- Rank variants
- Reveal a better way
- Strategize only
- Include extraneous information
- Omit necessary information

Tactics for promoting articulation discussion:

- Qualitative questions
- Analysis and reasoning questions
- Multiple defensible answers
- Require unstated assumptions
- Trap unjustified assumptions
- Deliberate ambiguity
- Trolling for misconceptions

Tactics for Questions (Beatty, 2005)

1. Remove inessential details to focus students' attention where you want it.

2. Have students compare two things. Their attention will naturally be drawn to the differences between them.

3. Ask a familiar question about an unfamiliar situation to draw students' attention to the ways the new situation differs from a familiar one.

4. Ask a series of two questions. The first is a trap intended to make students commit a common error. Before reviewing the first question, ask a second which makes them aware of the error they have just committed. This technique can help them discover the mistake they made.

5. Require students to use different representations. Ask them to explain in words the meaning of a mathematical formula. Ask them to use information from a graph in a mathematical formula. Ask them to graph data in a table.

6. Present students with a set of processes or objects and ask them to determine subsets within the items presented.

7. Direct the strategy to force students to use more than one method. If students commonly solve a type of problem one way, require that they use a different method.

8. Include extraneous information or omit necessary information so that students think more carefully about what they need to solve the problem. If they are always provided with only the information needed, an important part of the problem solving has been done for them. “Not enough information is given” can be the correct answer for some questions.

Work in pairs to write new question(s) using one or more of tactics.

Think about 3 areas: content, cognitive, metacognitive.

Share question.

- what tactics used?
- what is question testing?
- what messages are being sent about what you value students to learn & about the discipline?

Course level learning goals

Share your goals

- **Please share with all of us some of your course-scale learning goals**
- **What did you think about as you wrote these goals?**
- **Does assessing these goals seem problematic?**

CONTENT HABITS OF MIND

SKILLS AFFECTIVE BELIEFS

How do you structure a course to develop and target these goals?

- **Please share your ideas!**

Developing course-scale learning goals: An example from Modern Physics

- Goal: Apply knowledge of behavior of atoms and light to novel applications.
- Lecture: Structure of atoms, interaction with light, discharge lamps – students learn basic physics.
- Homework: apply knowledge of atoms and light to photomultiplier tubes and digital cameras.
- Exam Question: “Explain what would have to happen (in your example atom) for the electron in the atom to become free (unbound from the atom). Draw a diagram of a discharge lamp set-up, showing the voltage supplied by the battery and the location of the gas molecules where this would be a possible outcome. Explain your reasoning.”

Course-scale goal:

Course activities:	**Connected lecture or topic – scale learning goals:**
In class:	
HW:	
Exam:	
Other:	

<table>
<tr><td colspan="2">Course-scale goal: Apply knowledge of behavior of atoms and light to novel applications.</td></tr>
<tr><td>Course activities:</td><td rowspan="5">Connected lecture or topic – scale learning goals:

e.g. Be able to propose various strategies for redesigning the semi-conductor used in a digital camera detector to control the color of light it would detect and explain why these changes would lead to a change in behavior.</td></tr>
<tr><td>In class: Structure of atoms, interaction with light, discharge lamps – students learn basic physics. (Use clicker questions, student discussion)</td></tr>
<tr><td>HW: Apply knowledge of atoms and light to photomultiplier tubes and digital cameras. (Make students explain reasoning, draw connections between ideas and actual behavior and outcomes (e.g. the digital pictures), use multiple representations)</td></tr>
<tr><td>Exam: "Explain what would have to happen (in your example atom) for the electron in the atom to become free (unbound from the atom). Draw a diagram of a discharge lamp set-up, showing the voltage supplied by the battery and the location of the gas molecules where this would be a possible outcome. Explain your reasoning."</td></tr>
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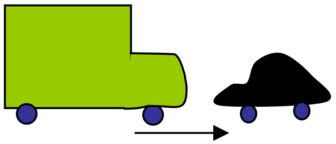
- **Work in pairs to examine how in your course you would address course-scale goal and how this is connected to lecture-scale goals.**

- **Share back with the whole group**

Examples for assessing course level goals

Measuring learning gains: Pre-post content surveys

Force Concept Inventory (FCI)
- Multiple choice conceptual content survey
- Given pre-post



Usefulness of Pre-post survey:

1) Pre-test:
- know students initial ideas
- establish baseline understanding

2) Pre-post:
- measure learning gain
  - for individual students, or class average

Normalized gain $$< g >= \frac{post - pre}{100 - pre}$$

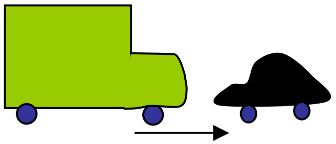
- measure effect of year-to-year modifications in course

Measuring learning gains

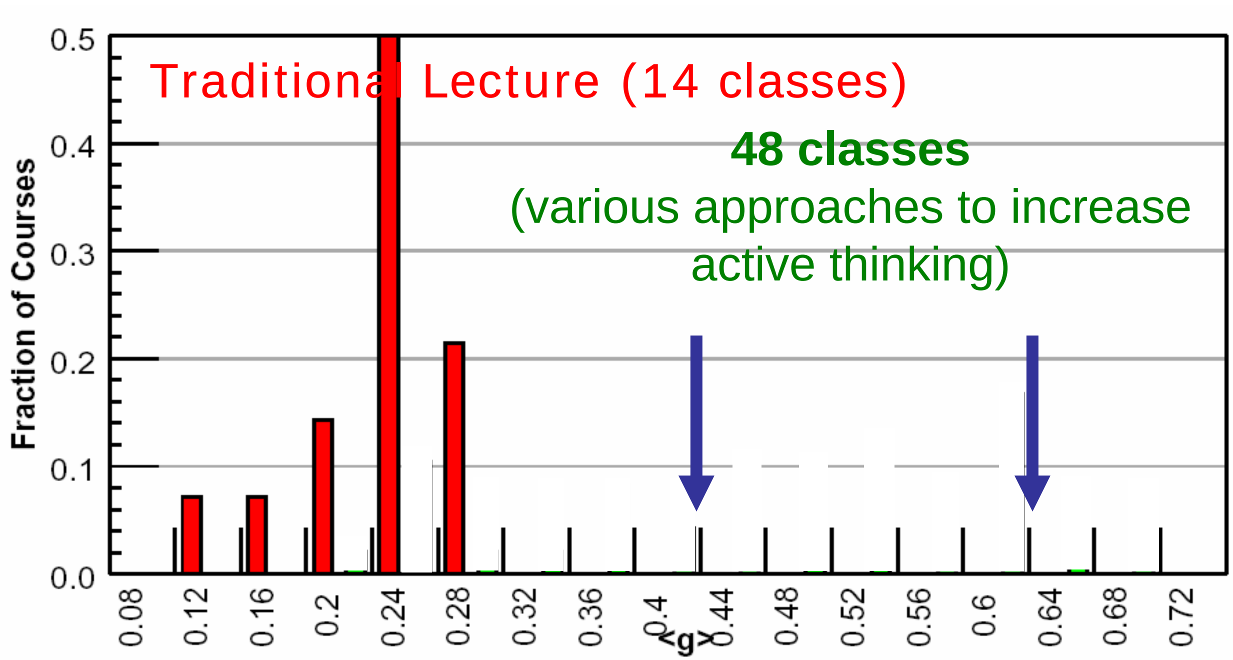
Pre-post content surveys:

Force Concept Inventory (FCI)

- Multiple choice conceptual content survey
- From Pre/post results, calculate learning gain



Normalized gain $<g> = \dfrac{post - pre}{100 - pre}$



Fraction of unknown basic concepts learned

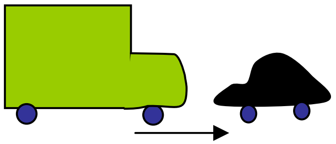
R. Hake, "…A six-thousand-student survey…" AJP **66**, 64-74 ('98).

Measuring learning gains

Pre-post content surveys:

Force Concept Inventory (FCI)

- Multiple choice conceptual content survey
- From Pre/post results, calculate learning gain



Using pre-post surveys:

- Maintaining integrity of the survey is key.
- Not administered as an exam (credit for participation but not graded)
- Establishing incentives for students to put in effort (use as a review for exam)

Creating pre-post content surveys

Basics:

1) Decide which specific learning goals to test (can't test them all in a ~30 min survey)

2) Formats: open-ended or multiple-choice or combo

3) * Multiple questions per concept/idea
   - can they use idea in different contexts
   * Distracters that represent common student misconceptions or problem solving difficulties

Validation (student and faculty interviews):

Are questions interpreted consistently by students/faculty? Is wording clear?

Are questions accurately capturing true misconceptions or true understanding of the concept/idea?

Time consuming

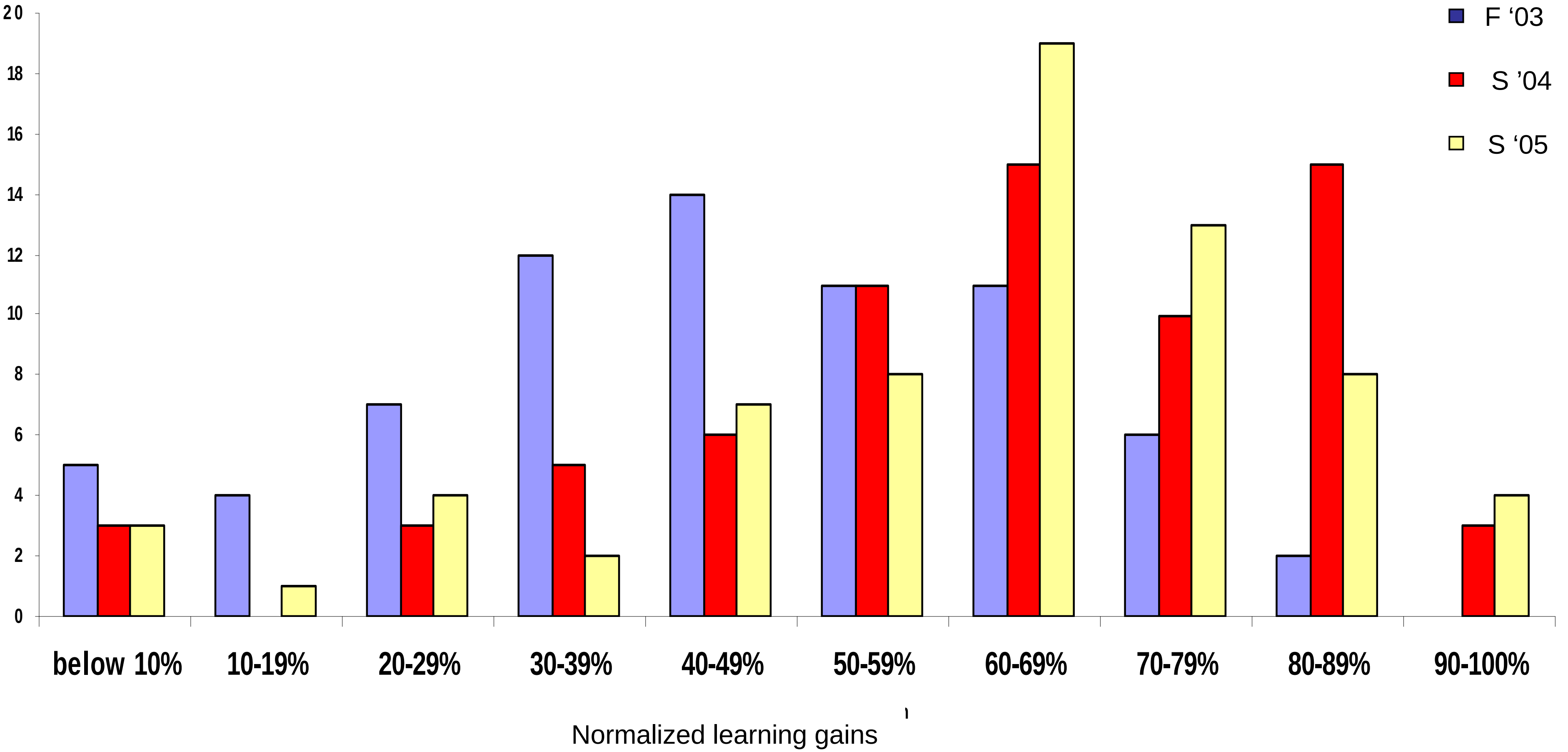
Parallels from physics to biology

Normalized average learning gains

from three semesters of Developmental Biology taught by the same 2 instructors with same syllabus

Traditional F'03	InteractiveS'04	Interactive S'05
46%	62%	61%

Learning gains in traditional (blue) vs. two semesters of interactive teaching (red, yellow)



Other ways to measure learning gains

- **Repeat challenging questions from semester to semester.**
- **Compare student performance**
- **Assess how students' answers change as you change the way you teach the class**

problem set questions
exam questions
final exam questions

Can all be used to collect this kind of feedback

Course-scale goal:
For students to think about science like a scientist!

The CLASS Survey

(Colorado Learning Attitudes about Science Survey)

Novice	**Expert**
Isolated pieces of information	Coherent framework of concepts
No connection to real world	Describes nature
Problem solving by matching to memorized recipes	Use systematic concept-based problem-solving strategies

Adapted from David Hammer (Cognition and Instruction)

The CLASS Survey
(Colorado Learning Attitudes about Science Survey)

- Design:
  - 42 statement, builds on previous work (MPEX[1] & VASS[2])

Strongly Disagree	1	2	3	4	5	Strongly Agree

I think about the physics I experience in everyday life.

After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.

- Score 'Overall' % Favorable :
  percentage of statements for which the student agrees with the expert

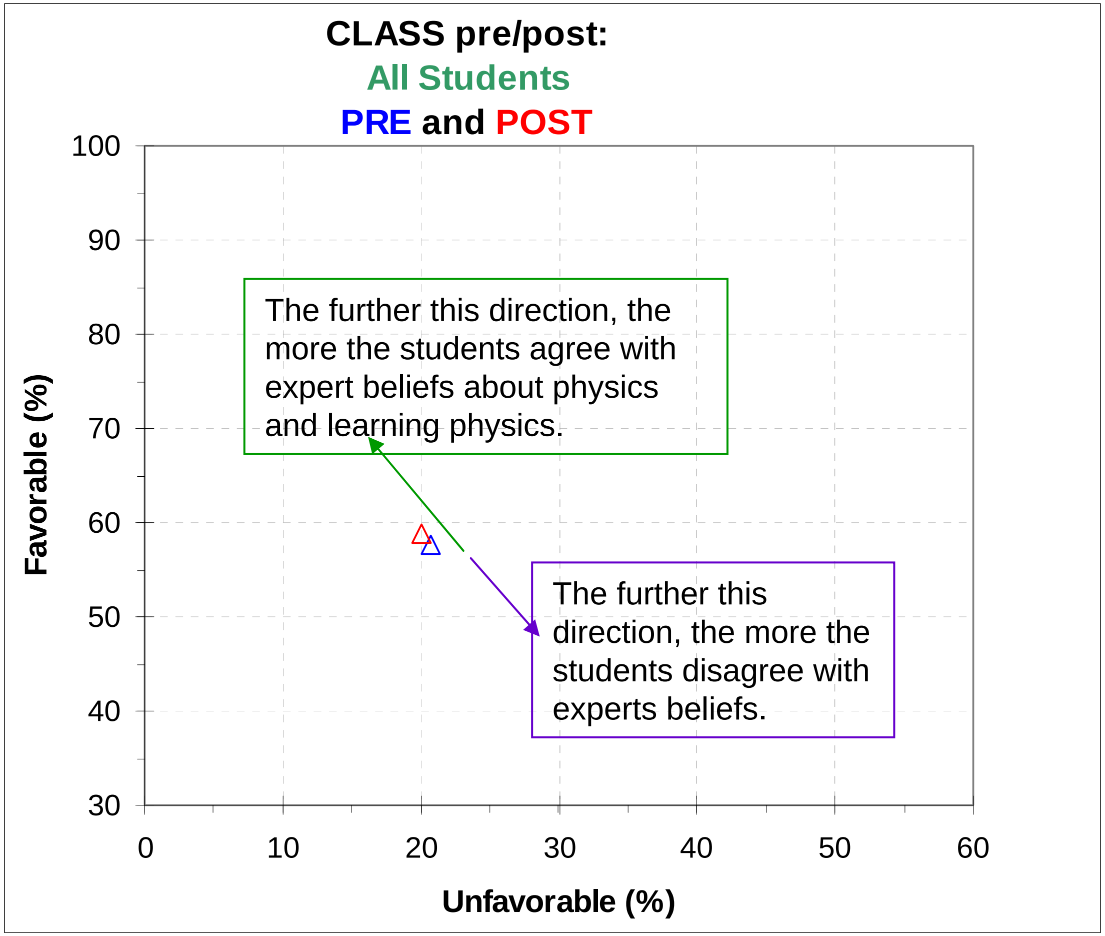
- Score 8 categories with 4-8 statements:

1. Redish, E., Saul, J. M. Steinberg, R. N., (1998). *Amer. Journal of Phys*.
2. Halloun, I. E., (1996). *Proceedings of the ICUPE.*

Measuring beliefs: CLASS survey

Categories

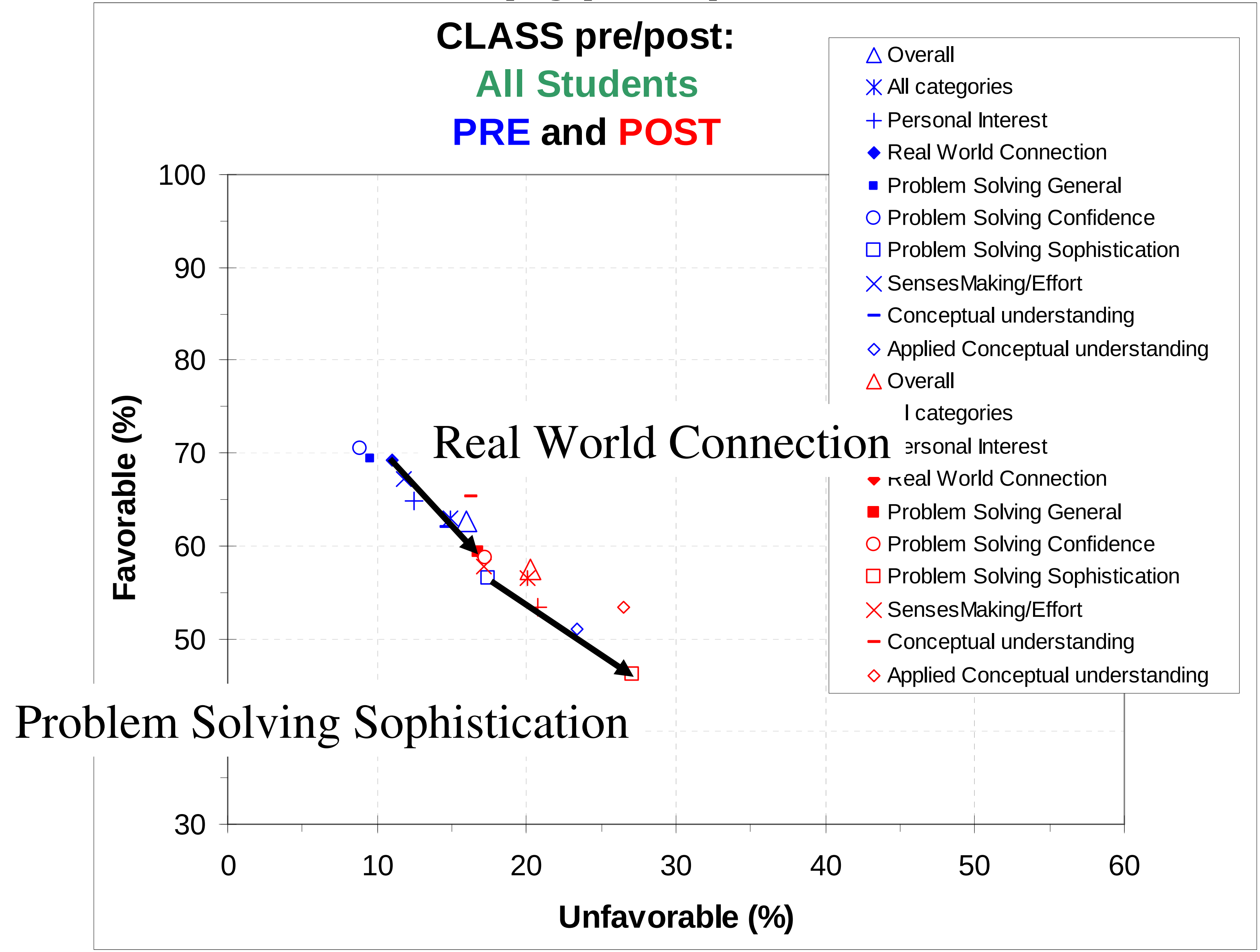
	# of students:305 PRE	POST	SHIFT
Overall (All 36 Q's with expert response) favorable	57.6	58.9	1.2
unfavorable	20.6	20.1	-0.5



% Favorable:
The students (on average) agreed with the experts on 57.6% of the statements

% Unfavorable:
The students (on average) disagreed with the experts on 20.6% of the statements.

(Typical) Shifts



W. Adams et al. 2004, replicating Redish, Steinberg, Saul AJP 66 p. 212 (‘98) workshop feedback

end