



# Workshop #4

## Best Practices/Teaching & Learning Methodology

NCLT Faculty Workshop  
for Learning and Teaching  
in Nanoscale Science & Engineering  
March 28, 2008

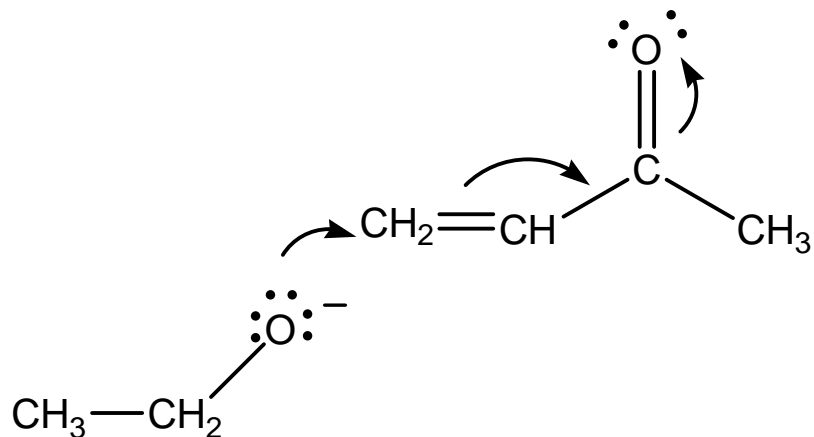


# Eternal Verities

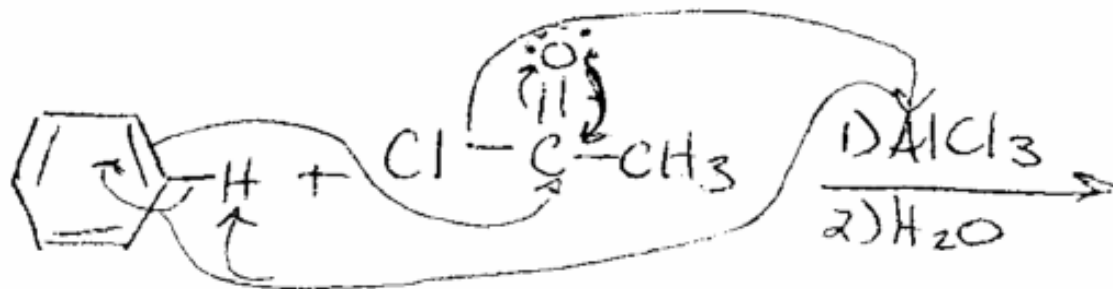
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- Teaching and learning are not synonymous; we can teach — *and teach well* — without having the students learn.

What was taught



What was learned



T. L. Anderson and G. M. Bodner, An Investigation of How Students Learn Organic Chemistry Reactions, *Chemistry Education: Research and Practice*, in press

- Teaching is something that has historically been done *to students*; not *with students*.

## Patricia Metz

... My frustration as a teacher started to mount when a student asked some questions on a point he did not understand. The professor responded to the first, then said he could not answer other questions because he had material to cover and limited time to do so. ...

Several days later when this same student raised his hand, he was ignored. No one ever again attempted to ask a question. The next point of frustration was the lecture notes.

At times I felt the professor's notes became my notes without passing through either of our minds.

- Knowledge is seldom transferred intact from the mind of the teacher to the mind of the learner.
- *Useful* knowledge is never transferred intact.
- Knowledge is constructed in the mind of the learner.

Write an equation that captures the following statement: “There are six students for every professor at this institution. (Use  $S$  for students and  $P$  for professors.)”


Which of the following did you write?

$$6 S = P$$

$$6 P = S$$

$$1 \text{ ft} = 12 \text{ in}$$

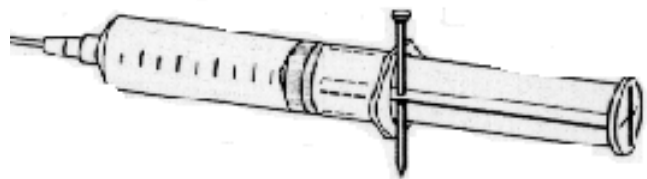
$$\# \text{ in} = 12 \times \text{ft}$$

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- I have abundant evidence that I can't teach chemistry.
  - What I can do is facilitate the learning of chemistry.

Example:


When I first took chemistry, a kind, old man told me that equal volumes of different gases at the same temperature and pressure contain the same number of molecules.

Until I took physics, this was the dumbest thing I had ever heard.



Gas	Weight of 50 mL of gas	Number of gas particles in 50 mL
H <sub>2</sub>	0.005	1 x 10 <sup>21</sup>
He	0.009	1 x 10 <sup>21</sup>
CH <sub>4</sub>	0.041	1.5 x 10 <sup>21</sup>
N <sub>2</sub>	0.055	1.2 x 10 <sup>21</sup>
air	0.056	1.2 x 10 <sup>21</sup>
O <sub>2</sub>	0.061	1.2 x 10 <sup>21</sup>
Ar	0.081	1.2 x 10 <sup>21</sup>
CO <sub>2</sub>	0.088	1.2 x 10 <sup>21</sup>
C <sub>4</sub> H <sub>10</sub>	0.111	1.15 x 10 <sup>21</sup>
Cl <sub>2</sub>	0.131	1.11 x 10 <sup>21</sup>
CCl <sub>2</sub> F <sub>2</sub>	0.228	1.14 x 10 <sup>21</sup>

G. M. Bodner, Why Lecture Demonstrations Are “Exocharmic” for Both Students and Their Instructors, *University Chemistry Education*, **2001**, 5, 1-5.

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- Understanding develops as knowledge becomes increasingly connected.

What is the difference between “good” students and “bad” students?

- No subject — with the possible exception of chemistry — is intrinsically interesting.

“I love Worcestershire sauce! I wish the oceans were full of ...”


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- People who don't want to learn usually don't; those who do want to learn may.

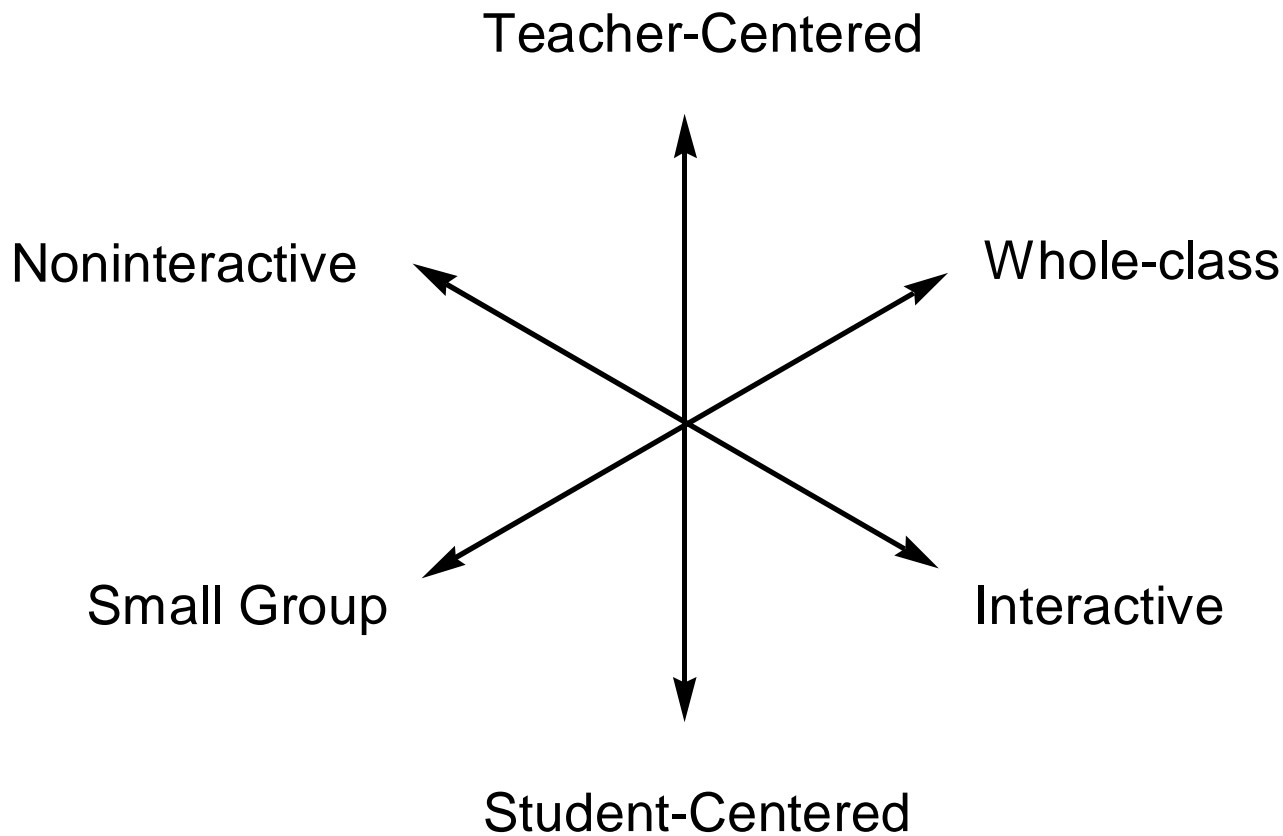
Ice is less dense than water, but steel is almost eight times as dense as water. Explain why both the Titanic and the iceberg it hit were able to float on water.

One student admitted: “I've been searching for a good explanation for this one for a long time.”


- When placed in a stimulating environment, with enthusiastic people, some who think they don't want to learn change their minds.

G. M. Bodner, I Have Found You an Argument: The Conceptual Knowledge of Beginning Chemistry Graduate Students, *Journal of Chemical Education*, **1991**, 68, 385-388.

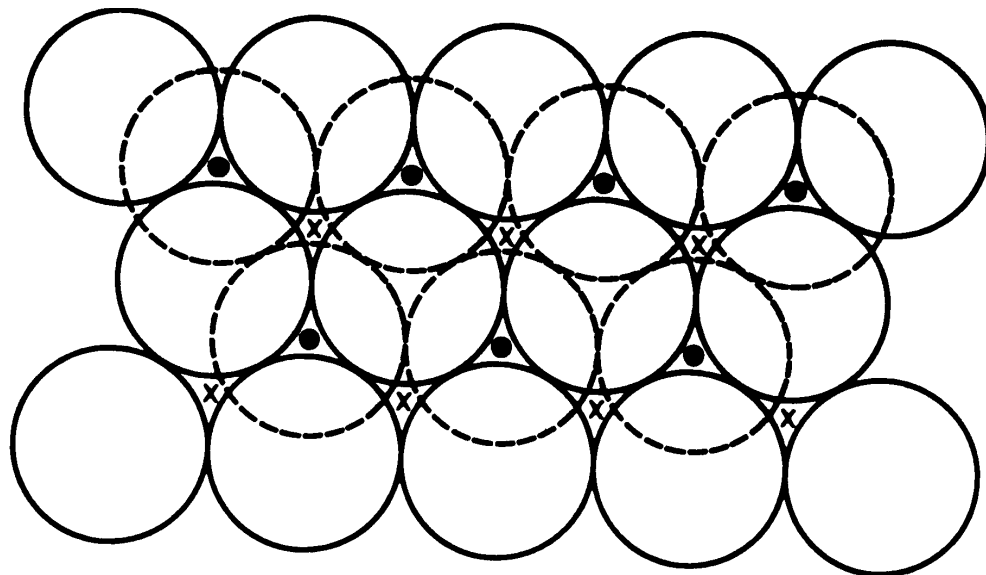
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- Science courses have historically used a format introduced in the 13th century — a series of lectures in which the state of knowledge in a field is summarized.
  - When this structure was introduced, there was no alternative. Books were rare; individual ownership of books even rarer.




G. M. Bodner, P. A. Metz, and K. Tobin, Cooperative Learning: An Alternative to Teaching at a Medieval University, *Australian Science Teachers Journal*, **1997**, 43(3), 23-28.

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- Lectures are the best way to introduce information when our role is the same as the masters who taught at medieval universities.
    - There is no text.
    - The content is dominated by facts, to be memorized, rather than concepts that must be understood.
    - Your role is that of a preacher.
  - Active students learn more than passive students

- Negative ions are larger (and positive ions are smaller) than the atoms from which they form.
- Negative ions are typically much larger than positive ions.
- Ionic compounds often crystallize in a structure in which the negative ions pack in a closest-packed array.
- Positive ions pack in holes between planes of negative ions.
- There are two kinds of holes in this structure: “x’s” and “o’s.”



- Content knowledge is necessary, but not sufficient.  
Imagine being asked to teach 4<sup>th</sup>-grade mathematics
- Good teachers have both pedagogical knowledge and pedagogical content knowledge.
- We are more likely to learn things that are taught than things that aren't taught.  
Imagine a natural products synthesis course that only discussed organic reactions.
- It is easier to learn something when you are perfectly clear what should be learned.  
Some argue that this is the function of the “lecture.”

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- Purposeful, directed learning is much more efficient when you get frequent, unambiguous feedback about your progress.

1966: 4<sup>th</sup> highest grade on PChem exam

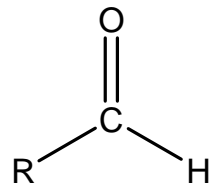
- Even when people want to learn, know what they are supposed to learn, are taught, and are told they haven't got it, they still may not learn.

Common explanations: The students are stupid, or they aren't ready to learn.

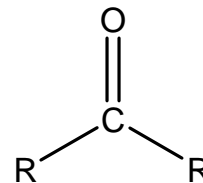
- The best way to organize information after it is understood is not necessarily the best way to organize it so that it will be understood in the first place.

- Things that make sense are remembered; nonsense isn't.

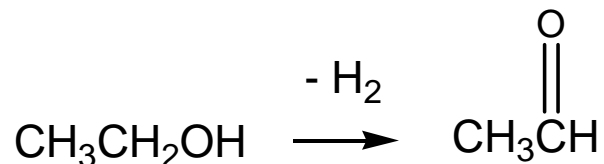
*Aldehyde:*



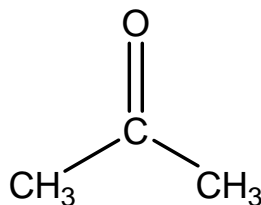
*Ketone:*



- *Aldehyde: Alcohol dehydrogenated.*



- *Ketone: Anything that reacts like acetone*



G. M. Bodner, Why Changing the Curriculum May Not Be Enough, *J. Chem. Ed.*, **1992**, 69, 186-190.

- It's hard to learn when taught in a language you don't know.

What do physical chemists have against diabetics?

*Adiabatic*

Why can't chemists be more positive?

*Cation*

Why can't organic chemists recognize a Lewis base when they see one?

*Nucleophile*

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- It's hard to learn when taught in a language that seems irrational.

What does it mean to “translate” from one language to another?

What do you do when you “conjugate” a verb?

- Language is seldom irrational to those involved in its development.

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- When taught at the same time, two closely related ideas are easily confused.

Molarity, molality, normality, formality, weight percent, volume percent, mole fraction, gram-atomic weight, gram-molecular weight, gram-formula weight, gram-equivalent weight, and the mole

- When one of the closely related ideas is thoroughly understood, the new one is quickly learned by contrasting it with the one we know.

Tornado Warning versus Tornado Watch

Hurricane Warning versus Hurricane Watch

- Learning requires a two-directional flow of information.
- No one in the classroom learns as much as the individual teaching the course for the first time.