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Terms of Engagement: a Framework for Assessing Different Modes of Student Interaction

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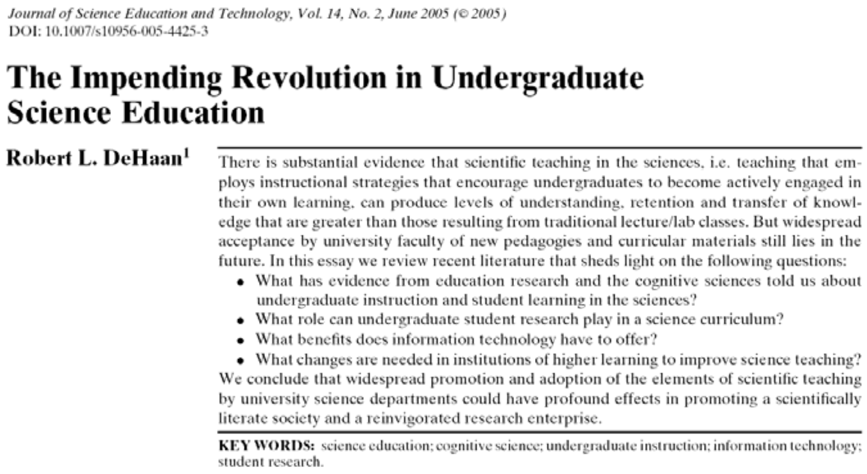
Skylight
The Science Centre for Learning and Teaching

So you want to have a revolution ...



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The Impending Revolution in Undergraduate Science Education

Robert L. DeHaan[1]

There is substantial evidence that scientific teaching in the sciences, i.e. teaching that employs instructional strategies that encourage undergraduates to become actively engaged in their own learning, can produce levels of understanding, retention and transfer of knowledge that are greater than those resulting from traditional lecture/lab classes. But widespread acceptance by university faculty of new pedagogies and curricular materials still lies in the future. In this essay we review recent literature that sheds light on the following questions:

- What has evidence from education research and the cognitive sciences told us about undergraduate instruction and student learning in the sciences?
- What role can undergraduate student research play in a science curriculum?
- What benefits does information technology have to offer?
- What changes are needed in institutions of higher learning to improve science teaching?

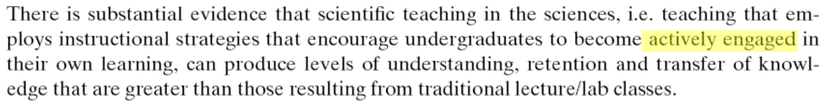
We conclude that widespread promotion and adoption of the elements of scientific teaching by university science departments could have profound effects in promoting a scientifically literate society and a reinvigorated research enterprise.

KEY WORDS: science education; cognitive science; undergraduate instruction; information technology; student research.

... then you'll need a good slogan

- "I am Spartacus!"
- "Give me Liberty or give me Death!"
- "Liberté, Egalité, Fraternité"
- "L'Union Fait La Force"
- "From each according to his ability, to each according to his need."
- "Political power grows out of the barrel of a gun."
- "Neither East nor West"

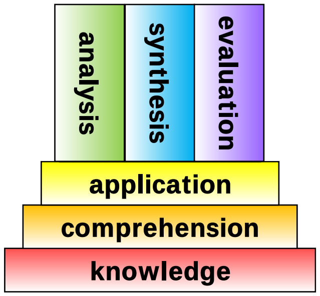
- ***"Engage your Students!"***
  - one useful strategy, but in what way, toward what objective?



There is substantial evidence that scientific teaching in the sciences, i.e. teaching that employs instructional strategies that encourage undergraduates to become actively engaged in their own learning, can produce levels of understanding, retention and transfer of knowledge that are greater than those resulting from traditional lecture/lab classes.

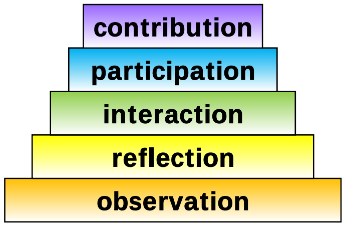
Engagement: to what end, and by what means?

Bloom's Taxonomy of Cognitive Skills



analysis | **synthesis** | **evaluation**
application
comprehension
knowledge

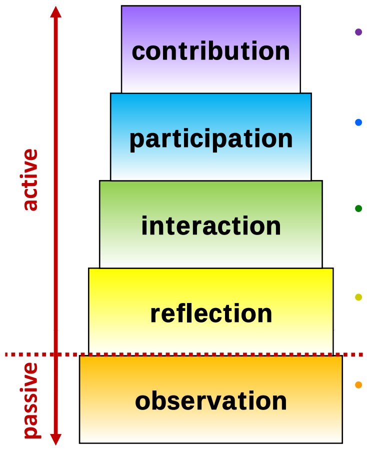
McNeil's Hierarchy of Student Engagement



contribution
participation
interaction
reflection
observation

Engagement: to what end, and by what means?

At each given level... **the student is:**



- creating and delivering course content
  e.g. student presentations, web pages
- presenting part of course content
  e.g. student-based demos, POGIL reports, PLTL
- responding, anticipating, questioning content
  e.g. asking/answering questions, peer discussion
- assimilating, thinking about, assessing content
  e.g. considering, contemplating, self-questioning
- receptive to / recording course content
  e.g. watching, listening, writing

Modes of engagement: a common analogy

Passive engagement

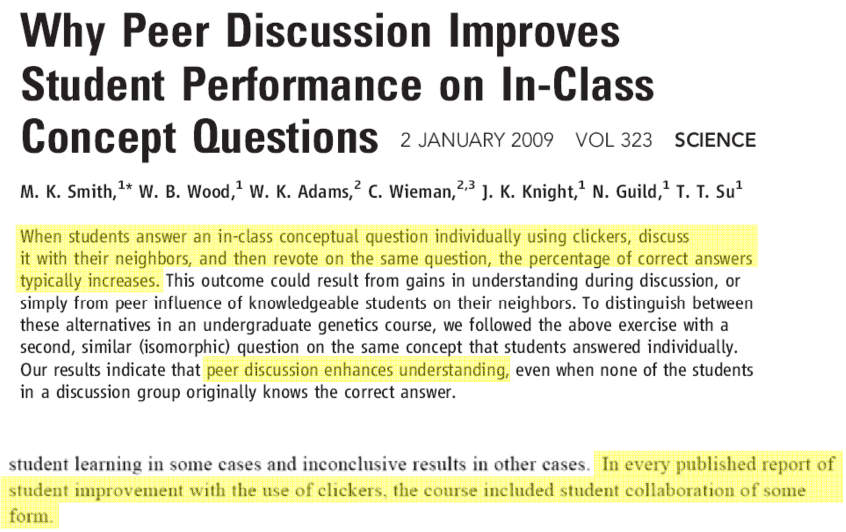
- e.g. traditional lecture
- sit, watch, listen:
  observation
- entertainment equivalent:
  television
- implication:
  about as useful and
  informative as TV, too

Active engagement

- e.g. clickers
- consider, respond:
  reflection, interaction
- true interaction?
- actual participation?
- genuine contribution?
- entertainment equivalent:
  80s text adventure game

```
It is pitch black. You are likely to be eaten by a grue.
What is the valence bond hybridization of orbitals at the
carbon atom in methane?
> sp²
Incorrect.  You have been eaten by a grue.
```

Engagement: effective only with goals in mind



Why Peer Discussion Improves Student Performance on In-Class Concept Questions 2 JANUARY 2009 VOL 323 **SCIENCE**

M. K. Smith,[1*] W. B. Wood,[1] W. K. Adams,[2] C. Wieman,[2,3] J. K. Knight,[1] N. Guild,[1] T. T. Su[1]

When students answer an in-class conceptual question individually using clickers, discuss it with their neighbors, and then revote on the same question, the percentage of correct answers typically increases. This outcome could result from gains in understanding during discussion, or simply from peer influence of knowledgeable students on their neighbors. To distinguish between these alternatives in an undergraduate genetics course, we followed the above exercise with a second, similar (isomorphic) question on the same concept that students answered individually. Our results indicate that peer discussion enhances understanding, even when none of the students in a discussion group originally knows the correct answer.

student learning in some cases and inconclusive results in other cases. In every published report of student improvement with the use of clickers, the course included student collaboration of some form.

Where do your students get (and share) information?

information source	interaction modes
Wikipedia	users edit and revise
Internet Movie Database	users contribute
Amazon	users contribute
Youtube	users create and contribute
Facebook	users create and contribute
your classroom	users watch, listen, have limited interaction

Case Study: the March of the Bonding Theories

Atomic Structure

- Rutherford Atom
- Bohr Atom
- Wave Mechanics
- Schrödinger Wave Equation

Molecular Structure

- Lewis Theory
- Valence Shell Electron Pair Repulsion Theory
- Valence Bonding Theory
- Ligand Field Theory
- Molecular Orbital Theory

These ideas resulted in Nobel Prizes to...

What Are Bonding Theories For?

Experiment without theory is blind,
but theory without experiment is mere
intellectual play

Bonding theories are tools. They help provide a conceptual framework for the understanding of physical and chemical properties.

Bonding theories are sets of principles used to explain observations.

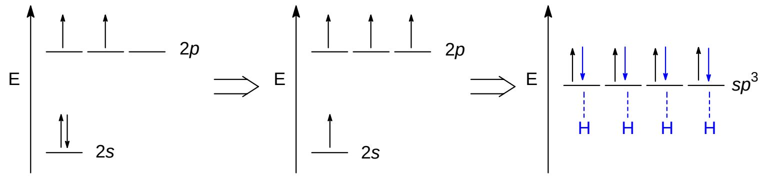
Bonding theories are not algorithms to memorize, or an end unto themselves, without any reference to the facts they explain.

Why do we teach them as if they were?

Asking The Right Questions

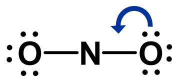
Bonding theories as an algorithm to produce the "right" answer

- Provide a valence bond promotion/hybridization diagram for the bonding in CH_4



- Draw a valid Lewis structure of the $[NO_2]^-$ ion, including formal charges on all atoms

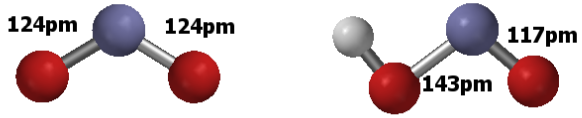
5
12
+1
18



Asking The Right Questions

Bonding theories as a means to explain experimental observation

- Use valence bond theory to rationalize the fact that methane has four bonds of equal length and strength, even though a carbon atom has atomic orbitals of different energy.
- Use appropriate Lewis structures and resonance forms to explain why the $[NO_2]^-$ ion has equal N-O bond lengths, but the HONO molecule does not.



Duelling Bonding Theories

How does it work?

- students are split into teams in a competitive quiz show
- asked to offer explanations for various observations in terms of competing assigned theories
- argue in favour of their own team’s responses to win points for each question

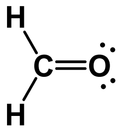
What are students doing?

- considering how to apply known ideas to new situations
- interacting dynamically with professor and other students
- participating in creation and delivery of course content

Duelling Bonding Theories

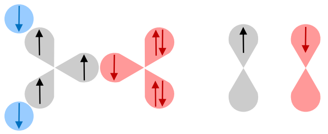
Lewis/VSEPR

- Team Captain: Gilbert Lewis, 1923
- bond = a pair of electrons shared between two atoms
- more e^- pairs = stronger bond
- geometry determined by e^- pair repulsion



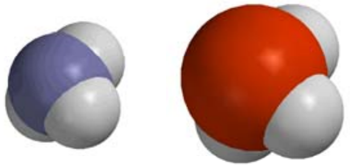
Valence Bond Theory

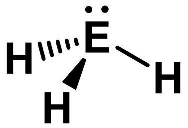
- Team Captain: Linus Pauling, 1948
- bond = spatial overlap of two orbitals (atomic or hybrid), with two e^- shared in the overlap region
- more overlap = stronger bond
- geometry explain by hybridization



Duelling Bonding Theories

NH_3 bond angle is 107°, AsH_3 is 91°





Lewis/VSEPR

- LP occupies greater volume than BP
- N $n = 2$, small distortion from tetrahedral (109.5°) angle
- As $n = 4$, larger LP yields larger distortion
- larger As = less steric repulsion of H atoms, so smaller angle possible

Valence Bond Theory

- N has smaller Z_{eff}, small ΔE between 2s and 2p, efficient hybridization, uses (approximately) sp^3 hybrids
- As has larger Z_{eff}, large ΔE between 4s and 4p, inefficient hybridization, uses p orbitals for bonding

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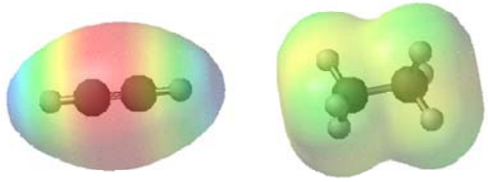
Duelling Bonding Theories

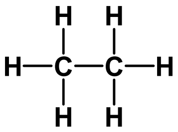
A C≡C bond is stronger than a C-C bond...



Lewis/VSEPR

- six e^- shared between two C, rather than two e^-
- more shared e^- = stronger bond

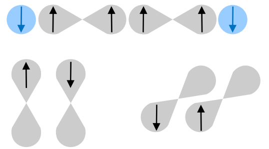
H—C≡C—H



$$H_3C-CH_3$$

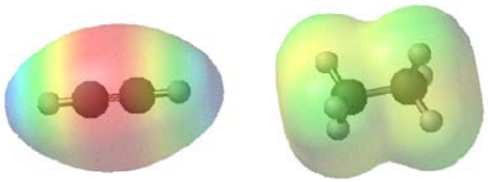
Valence Bond Theory

- three pairs of orbitals overlapping, six e^- shared
- greater overlap = stronger bond



Duelling Bonding Theories

...but not *three* times as strong (839 vs 347 kJ/mol)



Lewis/VSEPR

????

Valence Bond Theory

- three bonds are not equal
- triple bond = $\sigma + \pi + \pi$, σ bonds are generally stronger than π bonds
- 3x bond is <3x as strong

Duelling Bonding Theories

$SOCl_2$ is Lewis acidic at sulfur (despite LP!)

Cl_2 is yellow-green, Br_2 is orange, I_2 is purple

octahedral Co^{3+} complexes have either
0 or 4 unpaired electrons

H^- attacks BH_3 at B, w/o bond cleavage, but
H^- attacks NH_3 at H and breaks an N-H bond

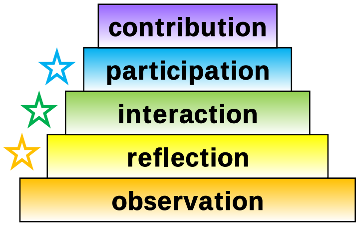
Which Tool Do I Choose?

- Qualitative structural data and bond strengths, polarity, some simple reactivity:
  Lewis Structures / VSEPR
- (Semi)-quantitative structural data and bond strengths (including IR spectra), localized bonding:
  Valence Bond Theory
- electronic spectroscopy (including colours), magnetism, electron energies, delocalized bonding, reactivity:
  Molecular Orbital Theory

Duelling Bonding Theories: Terms of Engagement

What are students doing?

- considering how to apply known ideas to new situations
- interacting dynamically with professor and other students
- participating in delivery of course content

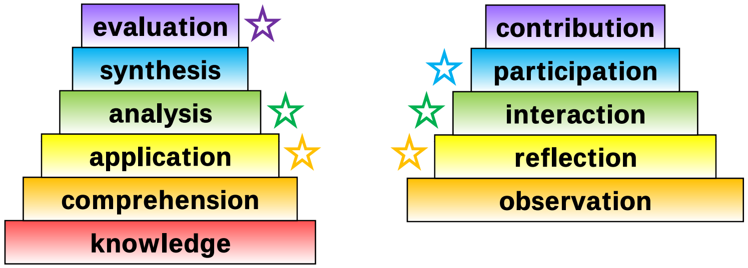


Duelling Bonding Theories: Terms of Engagement

What do students accomplish?

Students achieve

- practical application of bonding concepts to the analysis and rationalization of experimental observation
- evaluation of comparative utility and/or limitations of different theoretical models


evaluation ☆
synthesis
analysis ☆
application ☆
comprehension
knowledge

contribution
☆ participation
☆ interaction
☆ reflection
observation

Case Study: Protein Visualization

importance

- fundamental principle of biochemistry: “structure equals function”

challenges

- a complete understanding of protein function requires appreciation of multiple simultaneous aspects of macromolecular structure
- complex visualization tools, complex vocabulary for both structure and rendering
  - 1° 2° 3° 4° structures, chain topologies, sidechain interactions, substrate interactions in active site, metal ion geometries
  - “wireframe” “spacefill” “strands” “backbone”

Protein Visualization: current tools

many visualization tools available

- Chime, RasMol, RasTop, Mage, Protein Explorer, Deep View, PyMol, Jmol, etc etc

advantages

- instant and accurate depiction of experimentally determined 3D macromolecular structure (freely available at the Protein Data Bank)
- powerful control of multiple rendering schemes, permitting communication of different levels of information from same structure data
- free for academic use

disadvantages

- designed by biochemistry researchers for researchers – unintuitive command interface, requiring expert knowledge of biochemistry jargon and representation
- often stand-alone desktop applications, not Web-based

current tools

- very useful for visualization and presentation by experts
- not useful for exploration of protein structure by students
- not helpful to turn students *into* experts

UBCMol: designed for both instructors and students

user friendly

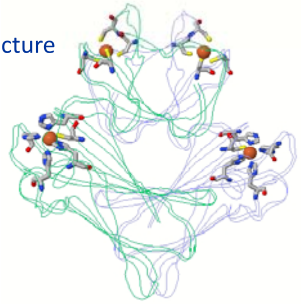
- self contained Java applet based on Jmol engine, additional javascript provides new intuitive interface
- encourages exploration of protein structure and program’s interface
- allows students to create and present their own interactive visualizations, rather than rely on static author- or instructor-designed images

useful in hands of instructor

- creation of course materials prior to lecture
- delivery and exploration of protein structures during lecture (with student suggestion and participation)

useful in hands of students

- exploration in guided inquiry assignments
- creation of interactive images for class presentations
- design of web pages for future course content delivery



UBCMol: tool for student engagement

student-directed class exploration

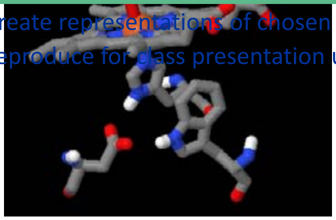
- display initial structure to class, ask for suggestions
- students analyze and interpret/explain structural results while instructor demonstrates use of the program

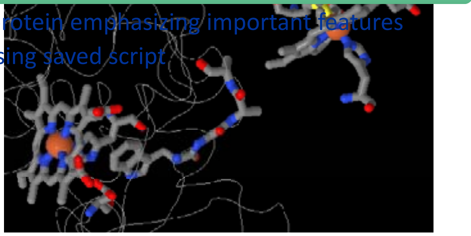
guided inquiry assignment

- discover / explore effect of heme axial ligand and nearby residues on protein function in myoglobin, cytochrome *c* peroxidase, catalase
- explore the electron transfer pathway in cytochrome *c* peroxidase

student presentations

- create representations of chosen protein emphasizing important features
- reproduce for class presentation using saved script





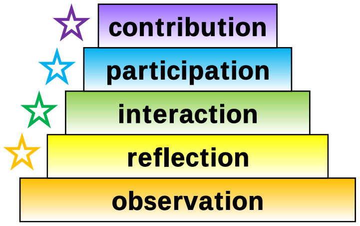
UBCMol: Student Feedback

- "It was nice to be able to rotate the molecules and to be able to zoom in on certain parts to see them more closely. The ability to identify key features of the proteins also gave me a greater understanding as to how structure affects the function."
- "It's extremely helpful that you can find and read a paper, and when they talk about specific residues you can simultaneously look for yourself at what they're describing. Having taken biochemistry courses ... you never really see this stuff but you're aware there is something deeper and more basic going on – [it lets you see] the underlying reason for all the things that get focused on in [biochemistry courses]."
- "It helped me to understand how the different amino acids come together [in a protein active site], and to be able to decide what I wanted to look at and how I wanted to see it."
- "I used this program in [a different biochemistry course]. We had an assignment that had us compare two different insulin proteins, and UBCMol helped me get a good view of the structural differences."

UBCMol: Terms of Engagement

What are students doing?

- thinking about what aspects of protein structure to explore
- interacting dynamically with the protein structure, either via the professor or the program itself
- participating in presentation of course content
- contributing to the creation and delivery of course content



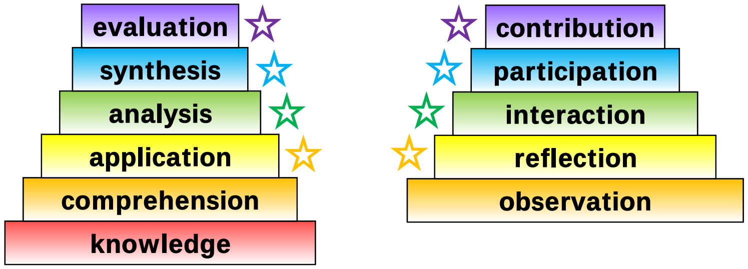
contribution
participation
interaction
reflection
observation

UBCMol : Terms of Engagement

What do students accomplish?

Students

- apply concepts of protein structure to exploration and analysis of specific proteins/enzymes
- formulate relationships between structure and function
- evaluate, select, and summarize structural information for presentation to other students



evaluation
synthesis
analysis
application
comprehension
knowledge

contribution
participation
interaction
reflection
observation

Conclusions and Acknowledgements

conclusions

- student engagement is an indispensible strategy to achieve a specific objective: engender more sophisticated student thinking, thereby improve student learning
- specific engagement tactics must be chosen with this objective in mind
- a hierarchy of different modes of engagement is a useful conceptual model to assess and aid the development of engagement tactics
- tools for student engagement are most useful when they can operate in different engagement modes

acknowledgements

- Irving K. Barber School of Arts and Sciences Curricular Innovation Award
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- students of UBC Okanagan Chem 220 and Chem 335

http://people.ok.ubc.ca/wsmcneil/