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Using 3D Water Models to Investigate Fundamental and Powerful Concepts in the Biological Sciences

Nora Egan Demers and Joanna Salapska-Gelleri

Florida Gulf Coast University, Fort Myers FL 33965 USA
(**ndemers@fgcu.edu**; **jsalapsk@fgcu.edu**)

Nosich defines fundamental and powerful concepts as those basic concepts that lie at the heart of a discipline (Nosich, 2005). When challenged to consider what such a concept might be in the natural sciences, water and its chemical properties emerges. I believe that students who demonstrate a strong understanding of the chemical bonding properties of water will perform better and understand more fully other important processes in the natural and biological sciences. To that end, we have incorporated activities using magnetic models of water (available from Milwaukee School of Engineering's (MSOE) Center for BioMolecular modeling) into activities in General Biology I classes at Florida Gulf Coast University. These models contain magnets that are used to help demonstrate the polarity of the molecule, and thereby provide an opportunity to build ice crystals, model cohesion and adhesion, and observe the solubility properties of water. We assessed students' ability to recall these chemical properties at several intervals in that class, and in upper division Biology courses. During this workshop participants will be able to work with the models, be exposed to the worksheet and hear about the assessment and results from our work at FGCU.

Literature Cited

Nosich, G.M. 2005. *Learning to Think Things Through: A Guide to Critical Thinking Across the Curriculum*. Second Revised Edition. Prentice-Hall, Upper Saddle River, New Jersey, 240 pages.

Supplemental Materials

The slide show/worksheet from the workshop is reproduced on the following pages. The complete set is also available at:
ww.ableweb.org/volumes/vol-32/demers/supplement.htm

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Nora Egan Demers
Joanna Salapska-Gelleri

ABLE 2010 DALHOUSIE UNIVERSITY HALIFAX, NOVA SCOTIA

32nd ABLE Annual Meeting
Dalhousie University
June 22-26, 2010

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Fundamental and powerful concepts

- Basic concepts that lie at the heart of a discipline (Nosich, 2005)

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Background- How we got here

- Whitaker Center sponsored
- support to attend Gordon Research Conference – (confidential)-
- but the NSF sponsors pre-conference workshops we can talk about!

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GRC VISUALIZATION IN SCIENCE & EDUCATION

July 3-8, 2005
The Queen's College
Oxford, United Kingdom

Whitaker Center for Science, Technology, Engineering and Mathematics Education

Whitaker Center for STEM education sponsored participation in GRC pre-conference workshop

- Introduced to concepts of
  - perception
  - storyboard methods to assess and compare textual to visual representations
  - Haptics- 3D molecular models magnets to show properties of water

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3-D Molecular Designs™
...where molecules become real™

Haptics-
3-D Molecular Designs
Models properties of water using magnets

Learning Outcomes cont'

- knowledge of emergent properties of water based on polarity (caused by differences in electronegativity)
  - Cohesion/Adhesion
  - Versatile solvent
  - Expansion upon freezing
  - Moderate temperatures (not addressed)
- Hydrophobic/ydrophilic
- data analysis especially variation

Integrate explanation into lecture interspersed with activities

Skills Acquisition

Critical thinking

Pipetting

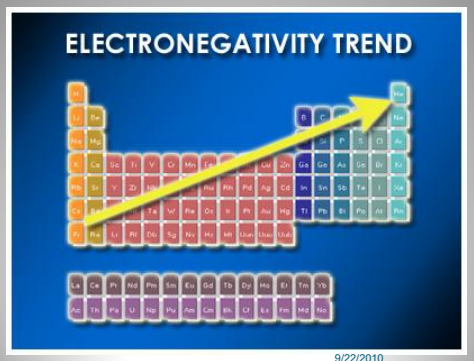
*Data analysis statistics

*Experimental variation vs natural variation

Scientific Process:

Building on prior knowledge

Electronegativity



"Teaching Cell" assignment 2006

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- Walks around loop road
- Lunch

Brainstormed on shared interests

IDS, learning, biology, cognition, etc

FGCU Demographics of course

- (Freshman) General Biology I for majors, health professions, forensics, environmental studies, marine science and General Education science with lab (semester-long)
- FGCU grew from 1500 students at inception in 1997 to over 10,000 FTE today
- **2006-2007 Freshman Class Profile**
  - Top 10 percent of high school class: 16%
    Top 25 percent of high school class: 46%
    Top 50 percent of high school class: 84%

Learning Outcomes

- Structure function relationship reinforced
- Greater understanding of role of electronegativity in emergent properties of water
- Types of bonds- Ionic vs Polar covalent bonds versus hydrogen bonds (inter vs intramolecular forces)

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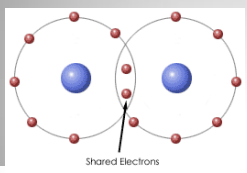
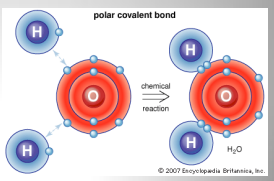
Polarity of water

What are types of bonds (recall from prior classes)?

- Bonding- covalent - sharing of electrons

If unequal sharing- polar covalent





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Polarity of water

- Explain how magnets simulate polarity of water brought about by **electronegativity**
- Note that colors for hydrogen and oxygen used are those used in most texts
- Model strength of polar covalent bonds by having them remove H from O

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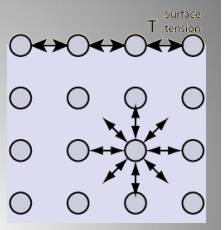
Cohesion/surface tension

- **Cohesion and Surface Tension**
- The cohesive forces between molecules down into a liquid are shared with all neighboring atoms. Those on the surface have no neighboring atoms above, and exhibit stronger attractive forces upon their nearest neighbors on the surface. This enhancement of the intermolecular attractive forces at the surface is called surface tension.



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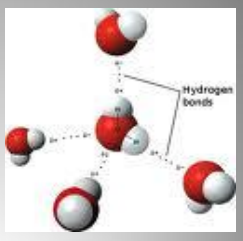
Cohesion in water

- How do well water molecules stick to each other?
- What do you recall about properties of magnets?
- note orientation of hydrogen to oxygen and similarity to magnets



Models sometimes are very realistic

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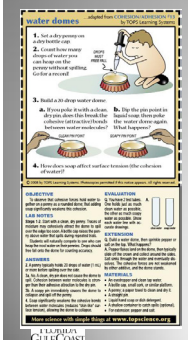
Cohesion/surface tension activity



How many microliters of water can you each place on a penny?

Collect class data analyze mean and standard error and

Compare to class height data (from previous lab)

compile reasons for variability in data collection and natural variation

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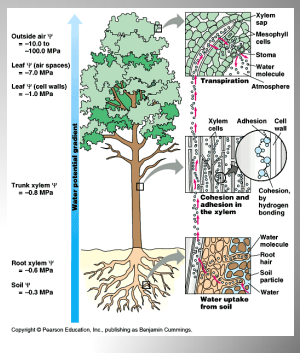
Cohesion/adhesion activity

- Practice with models - note how well they stick to each other
- Note how they stick to the white board and can be 'pulled' up (like water up a tree)



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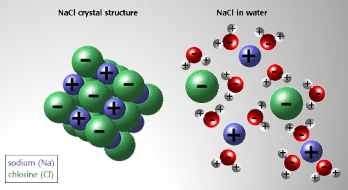
Solubility property of water

- Examine how sodium and chloride interact with water- note orientation of water molecules to element solubilized



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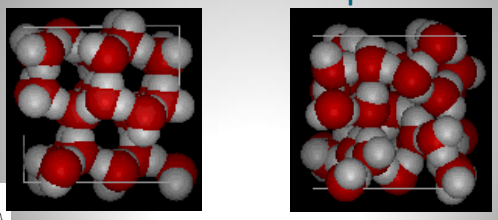
Ice lattice- right before break- competition between groups for ice-cycle 'cube' fastest then turn it back into liquid ☺



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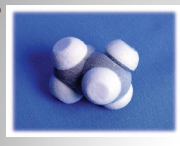
Hydrophobicity/hydrophilicty

- After break- preview of cell membrane properties

Look at gray model- what is different from water?



Replace one H with 'hydroxyl' group

How well do they stick to each other and to water models?

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What we did

- What is a "fundamental and powerful concept" in Biology (and other natural sciences)?
- Drafted storyboard to assess student understanding of knowledge before and after using cool magnets in hands-on learning approach in Gen Bio I
- Approach Ed. Researcher with idea- she suggested 3rd box to extend to assess their understanding of higher level application – how does water go up a tree?
- **Submit IRB and devise informed consent**

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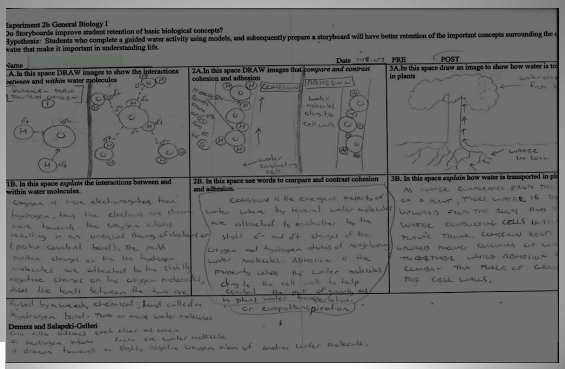

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Storyboard pilot

Invited colleagues to implement in their sections- we would score and return (if desired)

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What we did-variations on theme

- Pre-quiz
- "lecture"
- Activity, worksheet
- Post-quiz

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Pilot project- Storyboards on chemical properties of Water

Freedom for each instructor to implement as desired

- Allowed comparison of teaching methods

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Show rubric here

- Scored and refined rubric
- Check for consistency in scoring
- Entered data

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Preliminary Analyses Conducted

- Scores based on collapsed values for Boxes 1 and 2.
- Comparison of baseline knowledge for written versus graphic water properties.
- Gains from class activity as a function of Pre and Post test performance.
- Evaluation techniques: concurrent, homework, in-class post.

Pilot project- Storyboards on chemical properties of Water

Comparison of Methods

1. Pre-test, in-class activity, post-test.
2. Pre-test, in-class activity, post-test as homework.
3. Concurrent in-class activity and worksheet.
4. Laissez-Faire post-test.

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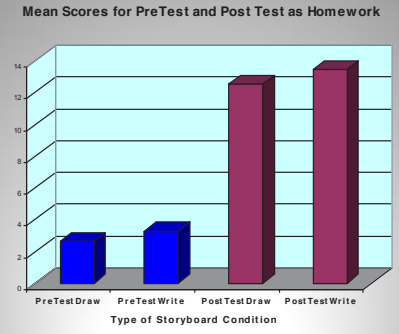

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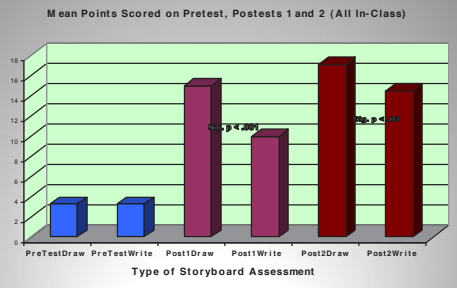
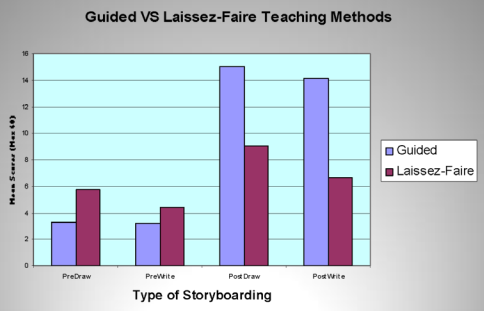
What did they retain?

- In two of sections the post was done again during DNA replication chapter
  - Tried to reinforced importance of distinguishing hydrogen and covalent bonding properties
  - Those data showed:





What we've learned so far- qualitative

- Motivation to complete task influences success at demonstrating concepts
- Motivations that are effective include grading (most importantly--it has to count!)
- They showed better learning on "post" that was homework or filled out during activity
- They need very careful guidance to be able to demonstrate even basic knowledge immediately after activity (spoon feeding?)

What else we've done

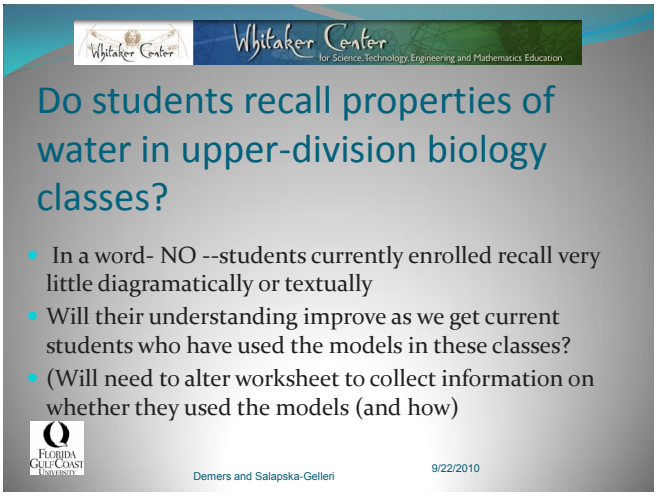
- Reassessed later in term and in upper-division classes
- Compare to other benchmarks
  class grade, etc
- Intro to Geology using models for role of water in properties of clay- comparing and refining teaching techniques. One faculty member now designs her entire class around water!
- (less success in getting biology colleagues to use models or assess learning of the concept as fully)
  - How might this be achieved?

Does knowledge of water properties relate to scores in upper-division courses?

Vertebrate Form and Function grade compared to worksheet score: worksheet completed first week of class as ungraded un-announced task. Very strong correlation to final grade in class (totally unrelated content).

Does this just tell us 'good students' are good at everything?

Can we find a way to see if knowledge of water improves success in other topics?



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