CH101/2 General Chemistry Hybrid Classroom Paradigm

Binyomin Abrams, Emily Allen, Dan Dill and Peter Garik
June 2013 Status Report

One of the most challenging aspects of introductory chemistry for students is their ability to conceptualize physical phenomena that cannot be directly observed; topics including energy, atoms, electron structure, and bonding can be difficult to learn because of their abstract nature. This, combined with the need to learn and integrate difficult concepts in the physical sciences and mathematics, can lead many students to struggle in general chemistry. For some students, the time in class is not enough to get a strong enough handle on the class content. For others, lecture-oriented courses does not give them the time to work through conceptual problems, necessary to develop depth of understanding. To address these difficulties, beginning in Spring CH102 2013 (with Tom Tullius) , we have begun to incorporate lessons reported by Carl Wieman ("Why Not Try a Scientific Approach to Science Education?", available a http://goo.gl/8ooA3 annotated by us in terms of what we are doing in CH101/2 General Chemistry) and others into a hybrid classroom paradigm. Adaptation of this approach accelerated in CH101 Summer 1 2013, and this progress is reported here.

By partially flipping the classroom, in-class time can be oriented at pulling out student preconceptions and addressing them directly with the support of group work and professor leadership. At home, students are given guided activities and interactive applets that are aimed at bridging the content learned between classes. Previous class information is further extended to help introduce the next section prior to class time. In all, the goal is to help students discover fundamental concepts in chemistry, through a modern and thoughtful presentation of the material. Overall, students will learn the material in a way that leads to better retention and translation of knowledge of the chemistry.

The pedagogical thought behind these activities follows four logics: just-in-time learning; one activity, one concept; show, try, ask; and spiraling to revisit and reinforce. goal of these activities is four-fold. First, the information is presented 'just-in-time,' making sure that students are exposed to problems and activities only when they are ready, not before. Second, each activity taken home focuses on one topic at a time to maximize the focus and understanding on each component. Third, the activities are set up such that students are shown a concept, given the opportunity to try for themselves, and then asked thought provoking questions to help increase the depth of understanding. Finally, the fourth aspect of these activities is to revisit previous concepts to reinforce the information, allowing for a spiral approach to presented concepts.

Summary of Activities

Many of the activities use online applications written using Wolfram Mathematical Computable Document Format (CDF) Technology. These CDF applications require the free CDF player plugin, available for all browsers at http://www.wolfram.com/cdf-player/

1. Traveling Waves
Module 1: Waves
Description: This activity is an introduction to traveling waves. It helps to identify the variables: wavelength, period, frequency, velocity, and wavenumber. It also uses graphing and observation to determine the relationship between these variables.
Applet: http://quantum.bu.edu/CDF/101/01-TravelingWaves.cdf

2. Resonance
Module 1: Waves
Description: This activity introduces and defines resonance in light and matter.

3. Introduction to Spectroscopy
Module 2: Spectroscopy
Description: Using an infrared absorption spectrum, the activity requires students to understand that the only interaction between light and matter happens at resonant frequencies.

4. Spectroscopy: Energy and Frequency
Module 2: Spectroscopy
Description: This activity relates energy to the wavenumber (and frequency) of spectral absorption. Through graphing and reading infrared spectral data, a relationship between frequency and energy is determined. Planck's constant is then calculated from this relationship.
Applet: http://quantum.bu.edu/CDF/101/06-Spectroscopy-3.cdf

5. Spectroscopy: Bond Energy
Module 2: Spectroscopy
Description: This activity continues the discussion of resonance by applying each absorption point in a molecule relates to a specific bond type. This relates the strength of the bond to the wavenumber of absorption. This is the first introduction to the role energy plays in resonant frequencies.

6. Introduction to Energy Diagrams
Module 3: Energy Diagrams
Description: This activity introduces students to energy diagrams, how they are different from graphs, and how to read them. This is meant to understand the basics of energy diagrams, and does not yet use real examples of reaction or atomic energy transitions.

7. Energy Diagrams and the First Law of Thermodynamics
Module 3: Energy Diagrams

Description: This activity introduces the first law of thermodynamics by showing how the energy of reactants and products change in chemical reactions. It uses energy diagrams to help calculate the energy change in determining the type of reactions that are occurring.

8. Spectroscopy: Electron Transitions and Light Emissions
Module 2: Spectroscopy
Description: This activity introduces the use of light emission to the energy changes within an atom or molecule. Through the use of green and red light, students are asked to determine which has the higher energy (based on wavelength), and what that means for the energy of an atom. The main focus here is that the energy of an atom changes through a transition between energy levels.

9. Spectroscopy: Balmer and Lyman Series
Module 2: Spectroscopy
Description: This activity continues from the emission of light to determine which transitions within an atom create the Balmer series and the Lyman series. Students are instructed to draw energy diagrams to help represent these transitions.

10. Spectroscopy: Hydrogen Atom
Module 2: Spectroscopy
Description: This activity uses the hydrogen visible light spectrum to solidify the relationship between frequency and change in energy, along with helping students determine the energy levels in hydrogen based on the transition energies.

11. Relationship Between *n* and Energy in Hydrogen
Module 4: Electrons
Description: This activity takes the energy levels of hydrogen, and the energy level number (n) and helps students determine the relationship between the two using graphs. Students are then asked to try and determine the Bohr model equation for energy (E_n).

12. Particle in a Box: de Broglie Wavelength
Module 4: Electrons and Module 1: Waves
Description: This activity introduces the wave-like properties of electrons such as delocalization and the de Broglie wavelength.

13. Particle in a Box: Standing Waves
Module 4: Electrons and Module 1: Waves
Description: Standing waves are introduced to help students determine how the wavelength changes based on the number of loops (n) and separation of the barriers of these waves. These barriers containing an electron wave are then defined using the particle in the box example.
Applet: http://quantum.bu.edu/CDF/101/12-ParticleInABox-1.cdf

14. Particle in a Box: Energy and Loops
Module 4: Electrons
Description: This activity looks at the energy levels of the particle in a box example and guides students through determining the relationship between the number of loops (n) of an electron wave to energy. Students graph each of these variables to determine their respective relationships.
Applet: http://quantum.bu.edu/CDF/101/13-ParticleInABox-2.cdf

15. Particle in a Box: Energy and Length of Box
Module 4: Electrons
Description: This activity looks at the energy levels of the particle in a box example and guides students through determining the relationship between the length of the box and energy. Students graph each of these variables to determine their respective relationships.
Applet: http://quantum.bu.edu/CDF/101/13-ParticleInABox-2.cdf

16. Particle in a Box: Coulomb's Law
Module 4: Electrons
Description: This activity is designed to guide students between the particle in a box energy relationship of $E_n \alpha n^2$ to the energy relationship they calculated using light spectra $E_n \alpha 1/n^2$ by showing how changing a basic infinite energy box into the coulomb's potential well transforms the relationship.

17. Photo-ionization
Module 3: Energy Diagrams
Description: This activity helps students to understand that as the number of energy levels in an atom increase, they develop into a continuum of energy values, asymptotically approaching zero. Using this transitions, students work through problems that help them determine the amount of energy needed to photo-ionize an atom and why this energy does not need to be a discrete value due to resonance.

18. 2D Electron Waves
Module 4: Electrons and Module 1: Waves
Description: This activity extends the students' understanding of one-dimensional standing waves by visualizing two-dimensional waves on an oscillating disk. Students are asked to count the number of radial loops within a 2D standing wave as well as how the wave changes with nodal planes.
Applet: http://quantumconcepts.bu.edu/software/applets/waves/index.html

19. 3D Electron Clouds: Quantum Numbers I
Module 4: Electrons and Module 1: Waves
Description: Students are introduced to three-dimensional waves and the description of electrons as energy clouds within an atom. Their shapes and energy are defined using the principle quantum number (n) and the orbital quantum number (l) within the hydrogen atom.
Applet: http://www.bu.edu/dbin/quantumconcepts/Hybridization/explorers.html

20. 3D Electron Clouds: Quantum Numbers II
Module 4: Electrons and Module 1: Waves
Description: Students are introduced to the momentum quantum number (m_l) and how it relates to the number of potential orbitals in the hydrogen atom as well as their orientation within the three-dimensional space. Students are also introduced to the idea of spin (m_s) and the Pauli exclusion principle. Students then practice identifying electron clouds using all four quantum numbers.
Applet: http://www.bu.edu/dbin/quantumconcepts/Hybridization/explorers.html

21. Electron Cloud Summary
Module 4: Electrons and Module 1: Waves
Description: This activity is a summary of the vocabulary and relationships between the concepts already covered: electrons, energy, delocalization, electron cloud, radial loops, nodal planes, and the four quantum numbers.
Applet: http://www.bu.edu/dbin/quantumconcepts/Hybridization/explorers.html

22. Introduction to Electron Density
Module 4: Electrons
Description: This activity bridges physical energy density of electron cloud to a graphical representation. Students are asked to interpret electron density graphs and describe the physical structure of the electron cloud at various points around the nucleus of an atom.

23. Electron Density: Hydrogen
Module 4: Electrons
Description: This activity has students create electron density graphs based on three dimensional electron cloud representations of the 1s, 2s, and 3s orbitals. By connecting the graphical representation with the physical structure of the electron clouds, students learn about the distribution of the delocalized electron throughout the atom and better understand the physical meaning of nodes.

24. Electron Density: Shielding
Module 4: Electrons
Description: This activity uses electron density graphs to introduce electron shielding in an atom. Students are asked to think about Coulomb's law in explaining the relationship between electron cloud distributions as a function of *r*, distance to the nucleus.

25. Factors of Electron Energy
Module 4: Electrons
Description: This activity has students summarize the four main components that play a role in the energy of an electron cloud: Nuclear charge, electron – electron repulsion, shielding, and separation between the electron and nucleus.

26. Electron Wave Interference
Module 4: Electrons, Module 1: Waves, and Module 5: AO and MO Theory
Description: This activity introduces students to basic wave interference. The resulting wave from destructive and constructive interference is then translated into the respective electron cloud density.
Applet: http://quantum.bu.edu/CDF/101/23-ElectronWaveInterference.cdf
Applet: http://quantum.bu.edu/CDF/101/1sMolecularOrbitals.cdf

27. Atomic and Molecular Orbitals
Module 5: AO and MO Theory
Description: This activity introduces the creation of molecular orbitals through the interaction and overlap of atomic orbitals. Students learn that the electron density can be used to better understand the overall energy change when molecular orbitals are created.

28. Correlation Diagrams
Module 5: AO and MO Theory
Description: This activity introduces students to correlation diagrams. The use of these diagrams show students how the creation of a molecule changes the energy of each atom, and what that means for the physical creation of the molecule (bonding and anti-bonding energies)

29. Atomic Orbital Overlap
Module 5: AO and MO Theory
Description: This activity guides students through the physical shapes of bonding and anti-bonding atomic orbital overlaps by asking them to draw molecular orbitals. Students are given examples of some of these overlaps and are asked to think about the orientation of each orbital when drawing.

30. Atomic Orbital Overlap and Energy Density
Module 5: AO and MO Theory
Description: This activity combines the ability to draw the physical, 3D representation of atomic orbital overlap and represent these orbitals graphically through their electron densities. Students are asked to think about how the electron density between the two nuclei of the molecule relates to whether or not the molecule forms.
Applet: http://quantum.bu.edu/CDF/101/1sMolecularOrbitals.cdf
Applet: http://quantum.bu.edu/CDF/101/2pMolecularOrbitals.cdf

31. Hybridization
Module 4: Electrons and Module 5: AO and MO Theory
Description: This activity contrasts atomic orbital overlap to the interaction and hybridization of electron clouds within a single atom. Students are then give examples of hybridization and asked to work through additional examples, their three-dimensional structure, and how energy is changed.

32. Bond Enthalpy

Module 5: AO and MO Theory

Description: This activity gives students a chemical reaction and asks them to use correlation diagrams and their knowledge of bonding and anti-bonding states of molecular orbitals to determine bond enthalpy.