Teaching using a hybrid course model: crafting and using effective out-of-class activities that engage and prepare students

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"Getting students engaged and guiding their thinking in the classroom is **just the beginning** of true learning, however**.** This classroom experience has to be followed up with extended "**effortful study**," where the student spends considerably more time than is possible in the classroom **developing expert-like thinking and skills.**"

-- Carl Wieman

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Outline

- Why do we need this?
- Hybrid course model for engaging students
- “JUST” model for out-of-class activities

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Students struggle

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Students struggle

Some students struggle in their first years in college because

- they don't know how to balance four classes
- they don't understand what we want from them
- they lack some of the more fundamental skills from high school
- they think that learning means showing up
- they hold on to major misconceptions about learning
- they need us to help them bridge the gap from high school to college
- …

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Students struggle

Students are unsuccessful at preparing for class because

- they "read", but like it's a story
- they "do problems", but rarely connect it to the course material
- they don’t have a gauge for what is expected of them
- they don’t seek help when they run into problems
- they are afraid to make mistakes
- …

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Students are most able to succeed when

- they prepare for class
- they are given context for their work
- they are given explicit expectations (low or high)
- they are supported and given guidance
- they are challenged to find answers for themselves

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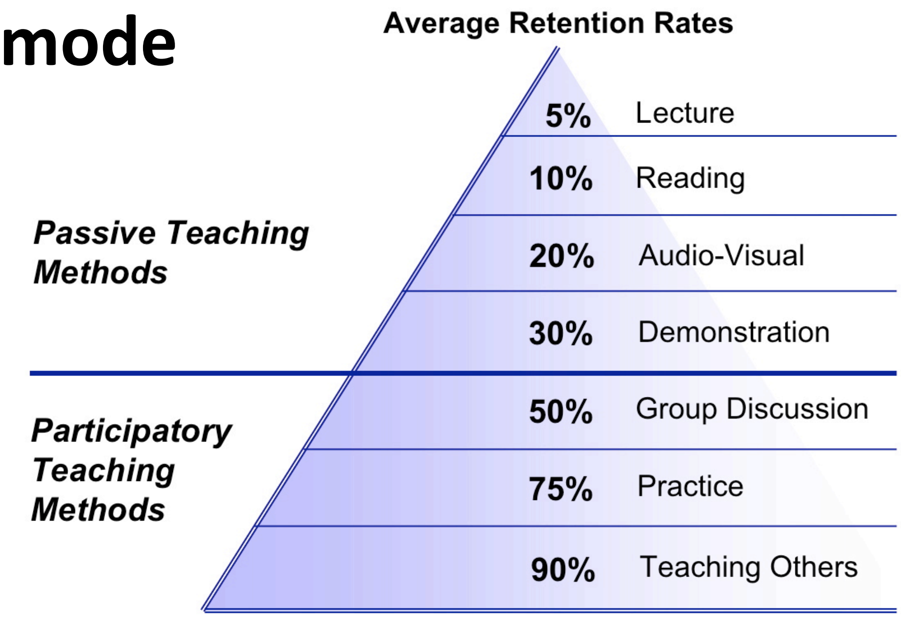
Our students crave the passive mode

- Students need to struggle to learn (research)
- Students accustomed to working hard, but ineffectively
  - Highlighter
  - Flash cards
  - Rewriting notes
  - Looking a problem solutions
- They interpret a lack of specific assigned work as an invitation to do little or no active work
- Courses that penalize group success de-incentivize many important forms of active learning



*Adapted from National Training Laboratories. Bethel, Maine

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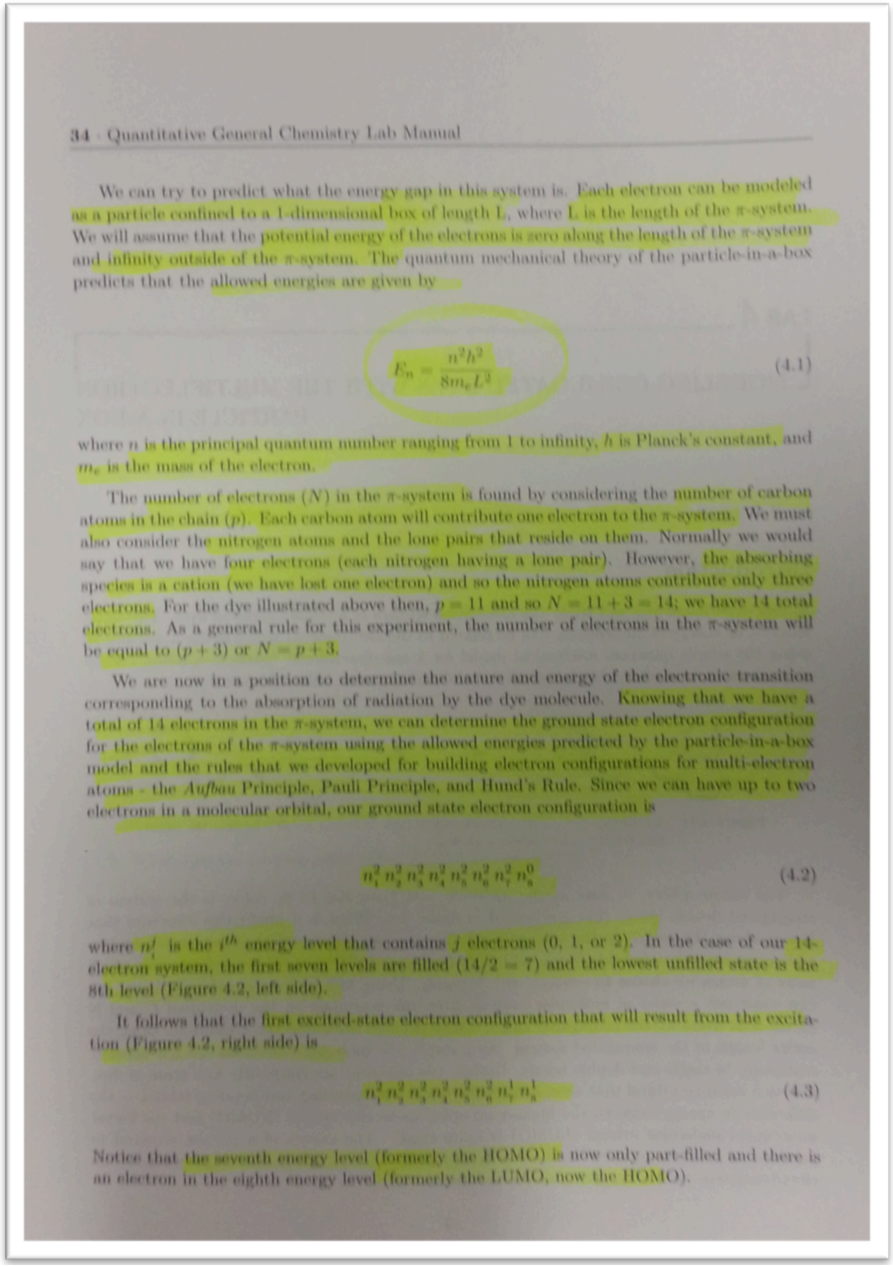

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We can try to predict what the energy gap in this system is. Each electron can be modeled as a particle confined to a 1-dimensional box of length L, where L is the length of the π-system. We will assume that the potential energy of the electrons is zero along the length of the π-system and infinity outside of the π-system. The quantum mechanical theory of the particle-in-a-box predicts that the allowed energies are given by

$$E_n = \frac{n^2h^2}{8m_eL^2} \quad (4.1)$$

where n is the principal quantum number ranging from 1 to infinity, h is Planck's constant, and m_e is the mass of the electron.

The number of electrons (N) in the π-system is found by considering the number of carbon atoms in the chain (p). Each carbon atom will contribute one electron to the π-system. We must also consider the nitrogen atoms and the lone pairs that reside on them. Normally we would say that we have four electrons (each nitrogen having a lone pair). However, the absorbing species is a cation (we have lost one electron) and so the nitrogen atoms contribute only three electrons. For the dye illustrated above then, $p = 11$ and so $N = 11 + 3 = 14$; we have 14 total electrons. As a general rule for this experiment, the number of electrons in the π-system will be equal to $(p + 3)$ or $N = p + 3$.

We are now in a position to determine the nature and energy of the electronic transition corresponding to the absorption of radiation by the dye molecule. Knowing that we have a total of 14 electrons in the π-system, we can determine the ground state electron configuration for the electrons of the π-system using the allowed energies predicted by the particle-in-a-box model and the rules that we developed for building electron configurations for multi-electron atoms - the *Aufbau* Principle, Pauli Principle, and Hund's Rule. Since we can have up to two electrons in a molecular orbital, our ground state electron configuration is

$$n_1^2 n_2^2 n_3^2 n_4^2 n_5^2 n_6^2 n_7^2 n_8^0 \quad (4.2)$$

where n_i^j is the i^{th} energy level that contains j electrons (0, 1, or 2). In the case of our 14-electron system, the first seven levels are filled ($14/2 = 7$) and the lowest unfilled state is the 8th level (Figure 4.2, left side).

It follows that the first excited-state electron configuration that will result from the excitation (Figure 4.2, right side) is

$$n_1^2 n_2^2 n_3^2 n_4^2 n_5^2 n_6^2 n_7^1 n_8^1 \quad (4.3)$$

Notice that the seventh energy level (formerly the HOMO) is now only part-filled and there is an electron in the eighth energy level (formerly the LUMO, now the HOMO).

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Why not "flip" the classroom?

What's good about flipping:

- Get students "working" outside of class (that's what we want!)
- Give support to students during problem-solving in-class

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Why completely flipped classrooms aren't the solution:

- Students do not get as excited for the material (infectious instructors are necessary here)
- Students often miss the contextual parts
- Students tend to learn material as "isolated fact nuggets" rather than developing understanding

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So assign a lot of homework!

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Goals for a hybrid model

- Remediate for missing pre-requisite knowledge / skills
- Engage students in active preparation for lecture
- Increase students excitement over subject material by providing context to the material
- Free-up lecture time for preconceptions, misconceptions, and deeper investigations

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Hybrid model

1. Prime students in lecture:
   - Give context and guidance
   - Set explicit expectations for learning outcomes (don't come back unless…)

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   - Challenging homework problems
   - Pair with Piazza or discussion board for great results

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4. Develop and extend during next lecture
   - Use class time to address confusion
   - Extended concepts and discuss applications

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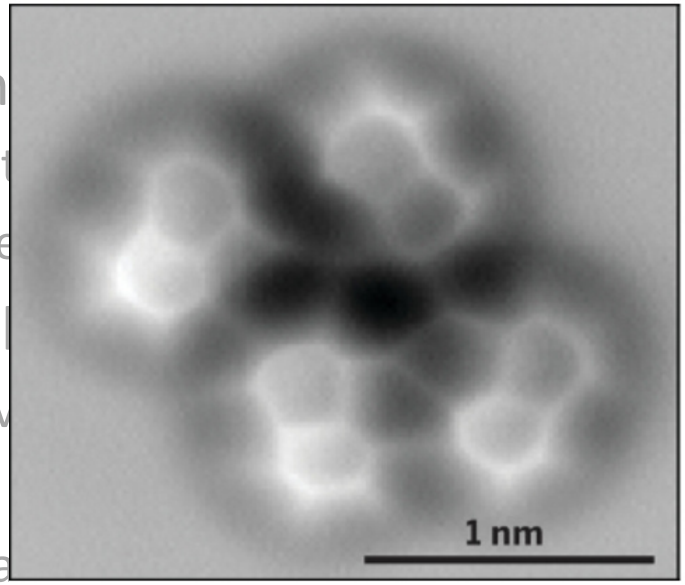
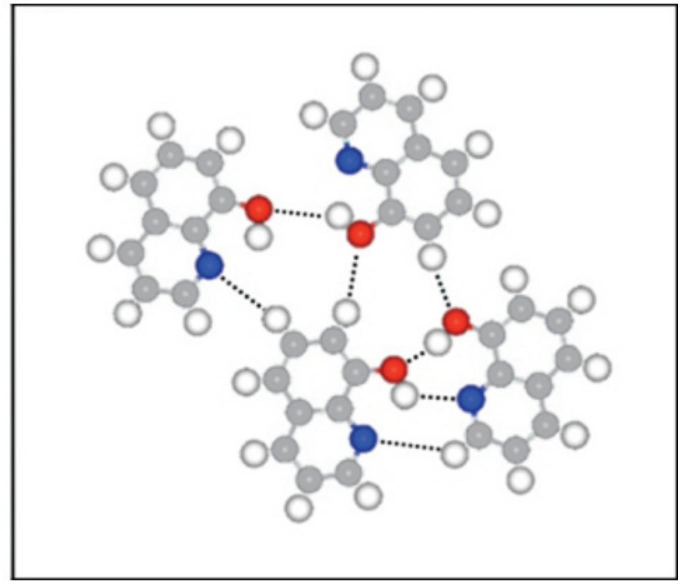
Hybrid model





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JUST model for effective out-of-class activities

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JUST Activities

Just-in-time

- Learned the hard way with *atoms-first* approach
- Eliminates the need for refreshers
- Helps students appreciate the fruit of their learning more quickly
- Enables students to focus on the material that is immediately relevant

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JUST Activities

Unburden

- Carrying a load of bricks
- Early versions of activities were less effective because students got lost too early

Intro
Idea 1

Idea 1
Idea 2

Idea 2
Idea 3

Idea 3
Idea 4

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JUST Activities

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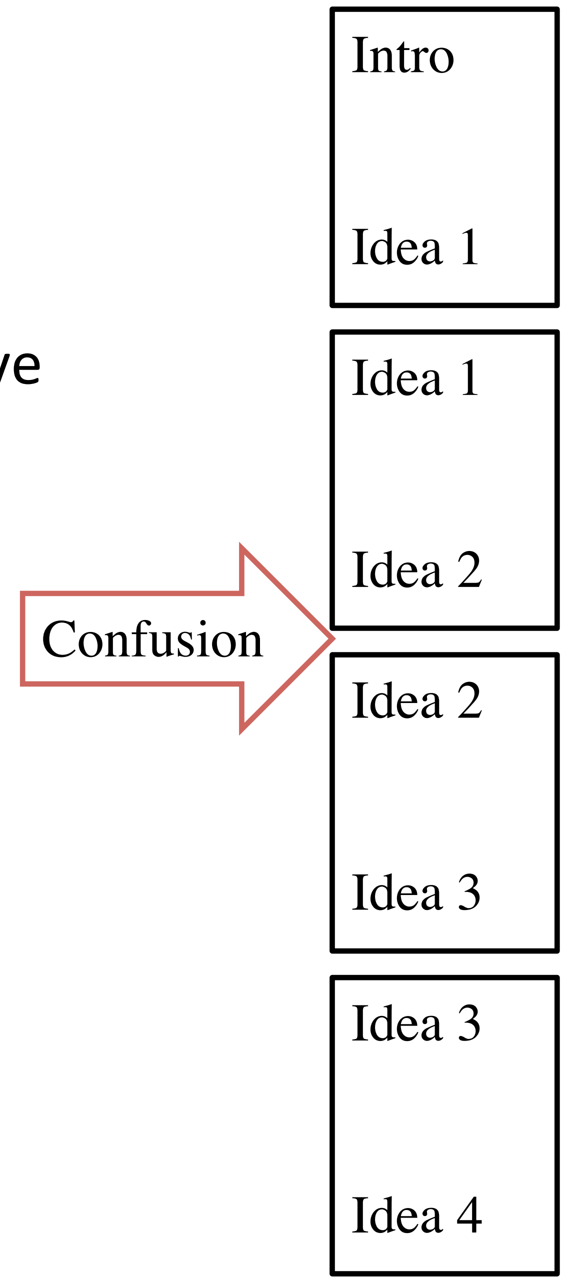

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JUST Activities

Unburden

- Carrying a load of bricks
- Early versions of activities were less effective because students got lost too early
- One activity = one concept
- Confusion (a good thing) occurs just when student is ready to go back to class/office hours
- Students arrive at class having prepared exactly the material we intend to present

Intro

Idea 1

Idea 1

Lead to Idea 2

New activity

Idea 2

Idea 2

Lead to Idea 3

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JUST Activities

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- Students struggled to figure out what they were supposed to do

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Show, Try

- Showing the students an example of what we're looking for substantially increases willingness to 'jump in'
- Some students stayed on 'auto-pilot'

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- Some students stayed on 'auto-pilot'

Show, Try, Think

- Final questions asking to apply and/or extend what they learned
- Students arrive at lecture curious / interested

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JUST Activities

Transfer

- Learning is slow; Spiral approach to teaching general chemistry
- Transfer of skills and learning critical in course
- Later activities draw on and reference earlier activities
- Early activities foreshadow later learning to come

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Different goals for activities

- Remediation of pre-requisite skills
- Skill building / confidence building
- Investigating basic concepts
- Exploring relationships and making connections

Different types of activities

- Answer questions by doing research
- Sketching, drawing, making analogies
- Play with widget (Mathematica CDF) to learn relationships
- Watch a video to get answers
- Engage in a student debate in groups

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How office hours have changed because of JUST

- Old "question" style: "I don't understand IR."
- New question style: "Can you explain to me how resonance in spectroscopy is related to energy?"

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How office hours have changed because of JUST

- Old "question" style: "I don't understand IR."
- New question style: "Can you explain to me how resonance in spectroscopy is related to energy?"

How lectures have changed because of JUST

- Old question style: "What is the relationship between wavelength and wavenumber?"
- New question style: "Why do spectroscopists prefer/choose wavenumbers over wavelength or frequency?"

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http://quantum.bu.edu/CDF/101/01-TravelingWaves.cdf

http://quantum.bu.edu/CDF/101/23-ElectronWaveInterference-1.cdf

http://quantum.bu.edu/CDF/101/IRFrequency.cdf

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"Do not let the math define the chemistry. I have seen myself and friends alike get wrapped up in equations, math, and rote calculations. The Chemistry defines the math, not the other way around. If one spends the time to fundamentally understand what is happening at a microscopic chemical level, then the math will explain itself."