Improving Science Pedagogy on Your Campus

2022 Institute for Chief Academic Officers with Chief Financial and Chief Enrollment Officers
Who is here (what position or office do you primarily fill at your college/university)?

- CAO
- President
- Provost
- CEO
- CFO
- Dean
- Professor
- Registrar
- Admissions
- Other
Presenters

**Amanda J. Brosnahan**, Dean, College of Health and Science and Associate Professor of Biology, Concordia University, St. Paul

**Benjamin Harrison**, Associate Professor of Biology, Concordia University, St. Paul

**Ian J. Rhile**, Professor of Chemistry and Biochemistry, Albright College
CIC Seminars on Science Pedagogy: July 2019 and July 2021

- Supported by a grant from the W.M. Keck Foundation
- CIC selected 9 institutions to participate each year
  - Each institution supported a team of 4 faculty
  - Extensive preparatory work prior to the seminar
  - At least 2 from each team taught at least 1 introductory course the following year, using methods learned in the workshop.
Goals: to improve teaching effectiveness and student learning in introductory biology, chemistry and physics.

Seminar methods based on research in cognition and neuroscience that have been shown to yield significant improvements in student learning in science at all levels.

Active learning model advocated by Stanford University physicist and Nobel laureate Carl Wieman, with colleagues at the University of Colorado at Boulder, the University of British Columbia, and Stanford.
Think-Pair-Share

What do you know about active learning on YOUR campus?
What IS active learning?
Active learning activities vary from simple to complex.
Active learning can be interspersed with lectures.

https://cei.umn.edu/teaching-resources/active-learning
Active learning decreases DFW rates.

- Freeman et al. metaanalysis of 225 papers in 2014.
- Student performance improves by 0.47 SD.
- Students performing in the 50th percentile of a class based on traditional lecturing would, in active learning classrooms, move to the 68th percentile of that class.
- Average failure rates were 33.8% with traditional lecturing and 21.8% under active learning.

Active learning increases student learning.


Active learning works across STEM disciplines.

The achievement gap for underrepresented students is well documented.

- Of those who declare a STEM major, the percentage who earn degree is (2019):
  - 43% of Latinx students
  - 34% of Black students
  - 58% of white students
- Intro courses are important: underrepresented students are significantly more likely to persist with a C or higher in general chemistry 1.

Active learning reduces the achievement gap for underrepresented students.

Plenty of research beyond our own is emerging that backs up the idea that inclusive teaching strategies can get us closer to our collective goals around equity. One such example is a meta-analysis of published studies in STEM. Researchers found compelling evidence that the kinds of pedagogies that are inclusive (i.e., active learning) reduce differences between minoritized and non-minoritized groups, but only when 67-100 percent of total class time was spent on active learning (Theobald et al., 2020). Thus, this kind of teaching is also an act of antiracism.

Hogan K. A.; Sathy, V. Inclusive Teaching, Strategies for Promoting Equity in the College Classroom (emphasis added).
The department is interested in increasing retention, especially in general chemistry. The College has DEI goals for increase retention in underrepresented students. Active learning present but not systematic.

Dr. Amy Greene
Dr. Nicholas Piro
Dr. Ian Rhile
Dr. Matthew Sonntag
Historically, Ian used lecture and problem solving sessions in general and organic chemistry.

- Traditionally, I used lecture with some active learning, albeit not in a structured way.
- Both courses have embedded problem solving sessions (1 out of 4 class sessions).
- In addition to the CIC seminar, I attended the Active Learning in Organic Chemistry Workshop in Summer 2022.
2021 CIC Seminar on Science Pedagogy

- Competitive proposal process
- 36 faculty from 9 CIC institutions
- July 12-16, 2021 (on Zoom, second offering after 2019 in-person)
- Topics include cognitive load, prior knowledge, deliberate practice, backward design, motivation, inclusive classroom, institutional change and others.
- Assessment from before the seminar and currently ongoing.
I have been using flipped format once per week for Organic Chemistry 1.

Flipped learning is a pedagogical approach in which first contact with new concepts moves from the group learning space to the individual space in the form of structured activity, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides the students as they apply concepts and engage creatively in the subject matter.

I have been using flipped format once per week for Organic Chemistry 1.

<table>
<thead>
<tr>
<th>Structured Preparation</th>
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<tbody>
<tr>
<td>Reading</td>
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<table>
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<tr>
<th>In-Class Teamwork</th>
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<tr>
<td>Mini-lecture on muddiest point</td>
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<tr>
<th>Post-Class Follow-Up</th>
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<tbody>
<tr>
<td>Additional Practice</td>
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</table>

All activities are based on course learning objectives.
The preparation for flipped classes is structured.

- Last question: What questions do you have about the material?
- Due 2 hours before class
- The pre- and post-class work structures their preparation for class (“two hours outside of class for every hour in class”).
Class time is divided into three parts.

- Answer questions about course content (10-15 minutes).
- Work on activities in teams (20 minutes).
- Report out on activities (10-15 minutes).
Reflections

- In general, students seem more engaged and have more of a community identity.
- The students who receive the most benefit for grades seem to be those in the C/D range.
- Other instructors have used worksheets, extensive polling (“clickers”) and gallery walk activities.
- Next steps: Some activities need tweaking; increase from one day per week to two or more!
The Science Department at Concordia University St. Paul

• Active learning had been a department focus for several years
• Elements of active learning had been integrated into almost every course
• We knew enough to know we could be better at using active learning techniques
• 4 of the 8 science faculty members attended the seminar: 2 chemists and 2 biologists

Dr. Mandy Brosnahan (Advanced Biology)
Dr. Ben Harrison (Intro. Biology)
Dr. Matthew Jensen (Intro. Chemistry)
Dr. Taylor Mach (Advanced Chemistry)
CSP’s BIO120 (Intro. Biology)
Pre vs. Post CIC Science Pedagogy Seminar

Class “Preparation”

Chapter Reading (broad)

In-class Team Work

Small Group discussion (informal)
Activities (Drawing, Role Playing, etc)
Sharing out (Large group discussion)

Post-class Practice

“Friday” Activities (peer-led), Online Review “Quiz”

Structured Preparation
(Activation of Previous Knowledge)

Targeted Reading
Pre-lecture Quiz (easy)

In-class Team Work

Brainstorming + Pattern Finding (Contrasting Cases and/or Venn Diagrams)
Activities (Clickers, Discussion Questions, Drawing, Role Playing, etc)
Sharing out (Large group discussion)

Post-class Practice

Drawing (less scaffolding, no notes), Mind Mapping, “Friday” Activities (peer-led)
CSP’s BIO120 (Intro. Biology)  
Pre vs. Post CIC Science Pedagogy Seminar

Pre: Classic lecturing - students passively listening

Post: Brainstorming, Contrasting Cases, Small Group Disc.

Osmosis

- A solute is any molecule dissolved in a liquid
  - Biologically relevant solutes include:
    - Salt ions
    - Nucleic acids
    - Proteins
- Cytoplasm has a number of different solutes in it
- When 2 solutions have different osmotic concentrations
  - Hypertonic solution has a higher solute concentration
  - Hypotonic solution has a lower solute concentration
- When two solutions have the same osmotic concentration, the solutions are isotonic

Membranes as Semipermeable Barriers (2-6)

Small Group Discussion: For each type of solution, where is there a higher concentration of solute - inside the cell or outside the cell?
### Unit 2 - Cell Structure, Membranes, Transport, and Signaling

<table>
<thead>
<tr>
<th>#</th>
<th>Outcome</th>
<th>Bloom’s Level</th>
<th>Study Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-1</td>
<td>List three main components of the Cell Theory</td>
<td>1. Remember</td>
<td>Flash cards</td>
</tr>
<tr>
<td>2-2</td>
<td>Compare and contrast the features of prokaryotic, eukaryotic (animal) and eukaryotic (plant) cells.</td>
<td>4. Analyze</td>
<td>Flash cards/binning</td>
</tr>
<tr>
<td>2-3</td>
<td>Recognize eukaryotic organelles in an image.</td>
<td>2. Understand</td>
<td>Drawing</td>
</tr>
<tr>
<td>2-4</td>
<td>Describe the basic anatomy, and function of phospholipids.</td>
<td>2. Understand</td>
<td>Flash cards/Drawing</td>
</tr>
<tr>
<td>2-5</td>
<td>Draw out a membrane labeling hydrophilic (polar) heads and hydrophobic (non-polar) tails</td>
<td>3. Apply</td>
<td>Drawing</td>
</tr>
<tr>
<td>2-6</td>
<td>Describe what a semipermeable membrane is.</td>
<td>2. Understand</td>
<td>Drawing</td>
</tr>
<tr>
<td>2-7</td>
<td>Compare and contrast the 4 types of protein-dependent transport that take place across the membrane</td>
<td>4. Analyze</td>
<td>Flash cards/drawing</td>
</tr>
<tr>
<td>2-8</td>
<td>Describe the mechanisms of bulk transport across membranes.</td>
<td>2. Understand</td>
<td>Drawing</td>
</tr>
<tr>
<td>2-9</td>
<td>Compare and contrast the 4 different types of cell signaling.</td>
<td>4. Analyze</td>
<td>Flash cards/mind map</td>
</tr>
<tr>
<td>2-10</td>
<td>Describe the 3 major steps of cell signaling.</td>
<td>2. Understand</td>
<td>Drawing</td>
</tr>
<tr>
<td>2-11</td>
<td>Describe the 4 different types of receptors.</td>
<td>2. Understand</td>
<td>Drawing</td>
</tr>
</tbody>
</table>
Climbing Up the Ladder

<table>
<thead>
<tr>
<th>Intellectual Skill</th>
<th>Study Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Analyze</strong></td>
<td><strong>Teaching/Explaining a concept to another person</strong></td>
</tr>
<tr>
<td>See connections between mechanisms</td>
<td><strong>Mind/Concept Mapping</strong></td>
</tr>
<tr>
<td>How mechanisms relate to one another</td>
<td><strong>Drawing and labeling (without notes!)</strong></td>
</tr>
<tr>
<td>Describing a mechanism or process</td>
<td><strong>Venn Diagrams</strong></td>
</tr>
<tr>
<td><strong>Apply</strong></td>
<td><strong>Listing/grouping terms together</strong></td>
</tr>
<tr>
<td>Grouping terms or proteins into mechanisms</td>
<td><strong>Organizing/boiling notes</strong></td>
</tr>
<tr>
<td><strong>Understand</strong></td>
<td><strong>Venn Diagrams</strong></td>
</tr>
<tr>
<td>Grouping terms or proteins into mechanisms</td>
<td><strong>Organizing/boiling notes</strong></td>
</tr>
<tr>
<td><strong>Remember</strong></td>
<td><strong>Quizlets</strong></td>
</tr>
<tr>
<td>Term definitions</td>
<td><strong>Flashcards</strong></td>
</tr>
<tr>
<td>Individual protein functions</td>
<td><strong>Re-reading notes</strong></td>
</tr>
<tr>
<td>Individual protein names</td>
<td><strong>Watching/rewatching videos</strong></td>
</tr>
</tbody>
</table>

Notice that re-reading text or notes and rewatching videos are off the bottom of this visual - they do **NOT** engage your brain enough to be considered studying!!!
Ben’s Reflection on the BIO120 revisions so far…

- The construction of quality, focused learning outcomes has made decisions during the revision process a lot easier.
- I feel we’ve finally putting the “Introductory” into Introductory Biology
  - Teaching students how to think and how to learn rather than an exorbitant amount of content.
- Students are demonstrating better learning practices in class and out
  - Asking questions that indicate higher levels of understanding
  - Recognizing what they need to review and study.
- While confounded by other revisions outside of new active learning techniques in class, our first exam had an average score that was ~10% higher than previous years.
What do the majority of science classrooms look like at your institution?

A: Tiered, all facing lecturer boards/screens at front

B: Large group discussion, some boards/screens around room

C: “Pods”, boards/screens surrounding classroom

I'm not sure
How can classrooms support active learning?
Classrooms to support active learning

Pods (or moveable desks)
Whiteboards (on walls or tables)
Space to move

Technology: Microphones & speakers
Multiple monitors (1 per group)
*hyflex options?
Faculty development

- Look for opportunities to train interested faculty
  - Conferences, seminars, webinars
  - Observe others that already do it
  - Paired mentoring

- Provide resources
  - Course release for significant changes
    - If not possible, support incremental changes (Flipped Fridays)
  - Support faculty groups that want to explore together (Faculty Coffee Hours)

- Provide feedback and support
  - Observe their efforts.
How do you continue to support active learning efforts?

Monitor Instructor & Students every 2 minutes

Active learning occurring?

Main things looking for:

- Lecture/listening
- Posing questions/answering questions/asking questions
- Writing on the board
- Working in small groups (and mixing with those)
- Clicker questions
COPUS Data: Traditional Lecture

Class Timeline
COPUS Data: Active Learning

**A general goal for the average class meeting is lecturing in 10-13 min chunks broken up by 5-6 min of an active learning activity.**
Think-Pair-Share

How might you better support active learning on your campus?
Resources (1)


Harris, R. B.; Mack, M. R.; Bryant, J.; Theobald, E. J.; Freeman, S. Reducing achievement gaps in undergraduate general chemistry could lift underrepresented students into a "hyperpersistent zone". *Sci. Adv.* **2020**, *6*, eaaz5687; DOI: 10.1126/sciadv.aaz5687.


Resources (3)


THANK YOU