Tools and Approaches for Engaging Students through Active Learning and Socio-Scientific Issues

Paul Laybourn
_Biochemistry and Molecular Biology_

**Goals and Objectives**

Goal: Instructors will consider employing active learning approaches

Objectives - Participants will:
1. be able to describe and explain active learning and socio-scientific issue based instructional approaches;
2. begin to redesign their own course using these approaches; and
3. begin to develop learning activities for their own course.

**Outline**

- Background on Scientific Teaching, Active Learning and Scientific Literacy
- Active Learning Activity Example 1
- Active Learning Activity Example 2
- Socio-Scientific Writing-to-Learn Activity
- Summary

**Scientific Teaching**

How can we actively engage our students with the content and process of science?

How can we increase student learning?

How can we recruit and retain population of diverse students in the sciences?
What is Scientific Teaching?

Scientific Teaching

• What do you think this means?

Today’s Workshop

• I Do
• We Do
• You Do
How People Learn

National Research Council 1999

Findings Include:

1. Learning builds on prior knowledge (must also address students’ misconceptions)
2. Making sense of factual knowledge requires a strong conceptual framework.
3. Learning is enhanced by the practice of monitoring it (metacognition)

What is Scientific Literacy?

• “…the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity” (NRC, 1996)
• Levels of scientific literacy (Uno and Bybee 1994)
  • Nominal level - recognize scientific terms
  • Functional level - apply scientific terms
  • Structural level - transferring concepts and describing them in their own words
  • Multidimensional level - examine socio-scientific issues and make decisions based on their scientific understanding

Achieving Scientific Literacy

Cognitive + Social Awareness = “authentic learners”
(Oers and Wardekker 1999, Brandsford et al. 2000)
How do you think undergraduate students answer this question?

What is the most important goal of a college education and, therefore, individual college courses?

A. Acquiring information (facts, principles, concepts)
B. Learning how to use information and knowledge in new situations
C. Developing lifelong learning skills

First-day questions for the learner-centered classroom, G.A. Smith, National Teaching and Learning Forum, Sept. 2008

The goal of Education is to make “experts” in the field

Recognizing Useful Patterns in Information
Experimental Result

Real Game

Random Pieces

Chase & Simon 1973

Experts

- Notice Meaningful Patterns of Information
- begin problem solving at “a higher level”
- Recognition triggers access to relevant knowledge.

Chase & Simon 1973

The Roles of Active Learning

Think like a scientist

Critical thinking skills

Science content knowledge

Expertise

New connections

Participation

Engagement

Attention

Martina Rosenberg

MWSI 2014
Interactive Instruction Increases Learning Gains

How do you learn?

Turn to your neighbor and put these 7 types of learning in order in terms of retention rate.

Backward Design – The Scientific Teaching Approach

Goals → Assessment → Instruction

Communication

Data

Experiment

What should students know, be able to do?

How will we and they know that they know?

How can we best prepare students?

Adapted from Wiggins and McTighe (1998)
Backward Design: Planning

Step 1: Developing your Objectives

- Your Turn!
  - Think – Pick a topic
  - Pair – Develop a learning objective
  - Share – With the class

LIFE 210 Introductory Cell Biology

Lecture 22
Nuclear-Cytoplasmic Transport
Active Learning Exercise

I. Did You Turn in Pre-class Homework Assignment on Canvas?

II. Introduction

III. Pre-activity iClicker Questions

IV. Hands-on Group Activity

V. Homework Assignments
**Learning Objective:** Integrate Concepts from Topics 1-4

**Parts:**
- nucleoporins, Ran-GTPase, Receptors, Ran-GAP, Ran-GEF

**Driving Forces:**
- ΔG and ΔG‡, ΔS and ΔH

**Background → Example 1 → Example 2 → WTL → Summary**

**Question 1.** Cargo proteins bind to ______ before they can be targeted to the nucleus?

A. import receptors  
B. nuclear localization signals  
C. nuclear export signals  
D. FG repeats
**Question 1.** Cargo proteins bind to _______ before they can be targeted to the nucleus?

A. import receptors  
B. nuclear localization signals  
C. nuclear export signals  
D. FG repeats

**Question 2.** Nuclear-cytoplasmic transport

A. requires protein unfolding.  
B. is catalyzed by Ran-GTPase.  
C. is driven by cargo concentration gradients.  
D. depends on Ran-GTP regulating cargo binding to their receptors.  
E. is catalyzed by cargo-FG repeat interactions through the nuclear pore complex.

**Question 3.** Nuclear-cytoplasmic transport

A. involves vesicular transport.  
B. is catalyzed by import and export receptor-FG repeat interactions through the nuclear port complex.  
C. involves Ran-GEF stimulation of the Ran GTPase activity in the cytoplasm.  
D. is the only transport mechanism that does not involve signal sequences or patches.  
E. is catalyzed by cargo-FG repeat interactions through the nuclear pore complex.
**Question 3.** Nuclear-cytoplasmic transport

A. involves vesicular transport.
B. is catalyzed by import and export receptor-FG repeat interactions through the nuclear port complex.
C. involves Ran-GEF stimulation of the Ran GTPase activity in the cytoplasm.
D. is the only transport mechanism that does not involve signal sequences or patches.
E. is catalyzed by cargo-FG repeat interactions through the nuclear pore complex.

**Question 4.** The protein that forms concentration gradients responsible for establishing the inside and outside of the nuclear envelope and providing the energy to pump molecules against a nuclear-cytoplasmic concentration gradient is

A. Ran-GTPase.
B. nuclear import receptors.
C. nuclear export receptors.
D. Ran-GAP and Ran-GEF.

**Diseases linked to protein nuclear-cytoplasmic trafficking mutations:**

- Various cancers, sex determination defects, bone fragility, muscle wasting disorders and neuronal diseases.
- In your folder is a slip of paper describing a specific mutation leading to disease.
- Before you can understand how this mutation can result in disease you need a clear understanding of protein nuclear-cytoplasmic trafficking.
- You will also be integrating nuclear-cytoplasmic transport with the previous concepts you have learned in LIFE 210.
**Hands-On Group Activity Instructions**

1. Form into groups of 3 students with your neighbors
2. Remove cards from envelope and deal them to group members
3. Earliest birthday plays first card (any card, player’s choice)
4. Subsequent player plays card they can justify as having a direct connection to any previously played card
5. Players have the option of passing or rearranging cards (as necessary) and helping one another.
6. Continue until all cards are played. You have 15 min.
7. This is not a competition within your group, this is a collaborative game!

---

**Hands-On Group Activity Intergroup Assessment**

8. Compare your results with your neighboring groups
9. Challenge differences and defend your choices
Predict how your group’s protein nuclear-cytoplasmic trafficking mutation will affect a protein’s normal function and lead to disease.

Confer within your group and be prepared to share your ideas with the rest of the class on the Canvas Discussion Board.

What types of mutations are not seen?

Homework (posted on Canvas Assignment Page)

As a follow-up to today’s activity please assemble a flow diagram/concept map for the following terms:

- Ran-GTPase
- import receptor
- export receptor
- Ran-GAP
- Ran-GEF
- nucleoporins
- FG (Phe-Gly) repeats
- nuclear and cytosolic fibrils
- NES
- NLS
- NES/NLS masking proteins and modifications

Summative Assessment: Exam Questions
Example 2: Gamification

Based on 1 versus 100 TV Show

PowerPoint Template Design: Tanya Buchan, TILT
$500
Interactions between a nitrogen and a hydrogen bound to an oxygen atom will be mediated by

A Van der Waals interactions.
B ionic bonds.
C hydrogen bonds.

$1,000
The following polypeptide is likely to form (non polar amino acids)
Gly-Leu-Asp-Lue-Ala-Lys-Ser-Leu-Arg-His-Phe-Cys-His-Ala-Ile

A A hydrophobic α-helix
B An amphipathic β-sheet
C An amphipathic α-helix
$2,000
The polar/nonpolar nature of amino acid R groups (side chains) are difficult to measure using free amino acids

A: Because the charged amino acids tend to associate and precipitate.
B: Since the R groups often switch from polar to nonpolar when amino acid is incorporated into a protein.
C: As a result of the polar amino and carboxyl groups found on each amino acid.

$3,000
Peptide bonds

A: Often break from chance intermolecular collisions.
B: Have planar structures.
C: Have Ψ but not Φ angles.

$4,000
Which of the following statements about aromatic amino acids is correct?

A: On a molar basis, tryptophan absorbs more ultraviolet light than tyrosine.
B: Histidine’s ring structure results in its being categorized as aromatic or basic, depending on pH.
C: The major contribution to the characteristic absorption of light at 280 nm by proteins is the phenylalanine R group.

$5,000
Which of the following statements about oligomeric proteins is false?

A: All subunits must be identical.
B: Some oligomeric proteins can further associate into large fibers.
C: A subunit may be similar to other proteins.
Increasing Scientific Literacy through writing

Writing-to-learn (WTL) enables students to:
- Engage in an iterative strategy that allows them to revise ideas
- Draw on different funds of knowledge (personal and academic) to support claims
- Describe decisions after weighing trade-offs
- Use informal reasoning that integrates ethical and cognitive perspectives

Writing to Learn
- Individuals organize their thoughts
- Evaluate evidence and their rhetoric
- Revise writing as they “see” their thoughts

Writing to Communicate
- Written work for others
- Writer must consider:
  - the audience
  - purpose of the written piece
  - the format
  - the style (expository, narrative, persuasive, etc.)

Balgopal & Wallace, 2013, The American Biology Teacher

Guided reflective writing activities enable learners to:
1. Identify and resolve scientific misconceptions
2. Address affective and behavioral, as well as, cognitive domains
3. Develop metacognitive skills
4. Use evidence to support claims
5. Employ higher levels of Bloom’s Taxonomy (analysis, synthesis, evaluation)

Cognitive-Affective-Behavior WTL Model

During iterative writing assignments centered on a Socio-Scientific Issue students can explore a topic from multiple perspectives

(Balgopal & Wallace, 2009)
Making science relevant

• Socio-scientific Issues (SSIs):
  • social issues for which scientific knowledge and understanding is important
  • no right or wrong answer
  • people use informal, moral, and scientific reasoning to resolve dilemmas
  • Examples: climate change, stem cell research, GMOs, fertilizer run-off, land use

Engaging students with SSI’s (and the “right” prompts!)

• Background info (course content, readings, videos, resources) should:
  • Be engaging, personal, and accessible
  • Provide ample scientific evidence and explanatory support for scientific concepts
  • Open the door to recognizing the role of personal and cultural knowledge

• Prompts should:
  • Be explicit and detailed about expectations

Example ‘generic’ prompts for iterative writing assignments on SSI’s

• Prompt 1: What do you know about this issue? Write a newspaper article to educate a target audience. Be informative about what the issue is, what causes it, and the consequences.
  • Engages the Cognitive Domain - Anticipate mostly Objective essays

• Prompt 2: How do you feel about this issue? Write a blog about how you imagine you or someone else might be affected by this issue.
  • Engages the Affective Domain - Anticipate mostly Subjective essays

• Prompt 3: What will you do or should others do to resolve any dilemmas relating to this issue? Write about this dilemma and any decisions to resolve.
  • Engages the Behavioral Domain - Anticipate mostly Authentic essays

SSI: Cancer Biology & Treatments – “collection of thoughts” + essay prompts

Three Key Topics – Three Essays (1-2 pages)
1. intermolecular interactions – anticancer drugs
2. transmembrane transport – multidrug resistance
3. metabolism - Warburg effect

WTL prompts (using graphic organizers)
1. What they know
2. How they connect/relate
3. What they would do/decide
4. Evaluation (self, peer, instructor)
How can we get students to organize their thoughts and their ways of knowing?

Article 1: Keeping Cells under Control: Enzyme suppression inhibits cancer spread
N. Seppa, Science 166: 134 August 28, 2004

Target Cancer: New Drugs Stir Debate on Rules of Clinical Trials
A. Harmon The New York Times September 18, 2010

Prompt 1: Imagine that a friend or relative of yours was diagnosed with cancer and was considering treatment with anti-cancer drugs. Think about how you might explain to them what you know about anti-cancer drugs and how they work.

Prompt 2: Consider your personal connections and reactions to what you know about anticancer drugs and their role in the treatment plan for this person.

Prompt 3: What actions might you take as you consider this imaginary situation of your friend or relative going through cancer treatment?

Essay Assignment: Use this information to construct a short essay (~1-2 pages) about the decisions you will make (i.e. what will you do) regarding anti-cancer drug treatment.

Graphic Organizers in Microsoft Word

Organizing thoughts about knowledge

FREE WRITE (like a journal entry)

EVIDENCE (the pieces of info that support the big idea)
Lecture Textbook Assigned article Prior knowledge

CLAIM (big idea)
How did students a) review their work, and b) get their work reviewed?

Self Evaluation
bold, underline, highlight their writing

Peer Evaluation
strengths and areas for improvement

Teaching Assistants
✔️- ✔️ ✔️+

Instructor Feedback In Class
Rubric for Peer Evaluators:

Please read the Collections of Thoughts from two of your peers in your randomly-assigned writing group. You will be providing feedback on their developing ideas and not on their writing mechanics (grammar, spelling, etc.). Remember to be respectful of your peers. Your comments are meant to be constructive and not pejorative. Make sure you identify some areas of strength as well as areas of potential improvement.

**Evaluation Element**

<table>
<thead>
<tr>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>√</td>
<td>+</td>
</tr>
</tbody>
</table>

The feedback constructively addresses the content of the collection of thoughts.

The feedback effectively addresses whether the content supports the thesis or not.

The feedback is forward-looking, providing helpful suggestions for improvement.

\[ -\times - = 0 \text{ points}; -\times , ,\times = 0.5 \text{ points}; -\times , ,\times = 1 \text{ point}; -\times , ,\times = 1.5 \text{ points}; , ,\times = 2 \text{ points}; , ,\times + = 2.5 \text{ points}; +, , + = 2.5 \text{ points} \] per peer evaluation with a maximum of 5 points possible for both peer evaluations.

---

**Step 2: Developing our Assessments**

- **Your Turn Again!**
  - **Think** – Pick a new learning objective or use the same one
  - **Pair** – Develop an assessment/activity
  - **Share** – With the group

---

**Step 3: Infuse Active Learning Into Your Course! (The You Do Part)**

---

**Rubric for WTL assignments (Collections of thought and essay)**

<table>
<thead>
<tr>
<th>Evaluation Element</th>
<th>Below Expectations (-)</th>
<th>Meets Expectations (√)</th>
<th>Exceeds Expectations (+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Accuracy of scientific information provided</td>
<td>-</td>
<td>√</td>
<td>+</td>
</tr>
<tr>
<td>B. Knowledge presented is from multiple sources (e.g., lecture, reading, other coursework)</td>
<td>-</td>
<td>√, √</td>
<td>√, +</td>
</tr>
<tr>
<td>C. Various sources and evidence are included, accurately represented, and carefully weighed</td>
<td>-</td>
<td>√</td>
<td>√</td>
</tr>
</tbody>
</table>

**Essay:**

<table>
<thead>
<tr>
<th>Evaluation Element</th>
<th>Not Evident (-)</th>
<th>Evident (+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D. Essay based on Pre-Writing Tools submitted by due-date</td>
<td>-</td>
<td>√</td>
</tr>
<tr>
<td>E. Responding to peer feedback is evident at the end of their Essay (Student includes two bulleted points of how they responded or why they did not get feedback)</td>
<td>-</td>
<td>√</td>
</tr>
</tbody>
</table>
Suggestions For Activities

- Question/response, think-pair-share
- Clickers
- Student presentations
- Learning-cycle
- Peer-Led team learning
- In-class learning activities
- Problem-based learning, case studies

Allen and Tanner CBE 2005; see also chapter 2 Handelsman et al. 2007

Resources for Developing Learning Activities

Scientific Teaching Series Videos:
http://www.ibiology.org/scientific-teaching/active-learning.html

Summer Institutes on Scientific Teaching:
http://www.summerinstitutes.org/

Mobile Summer Institute – CSU May 2018 and 2019

Scientific Teaching by J. Handelsman, S. Miller and C. Pfund 2007

“Infusing Active Learning into the Large-enrollment Biology Class: Seven Strategies, from the Simple to the Complex”, D. Allen and K. Tanner Cell Biology Ed. 2005

Acknowledgements

Collaborators
WTL
Meena Balgopal
Paul Laybourn
Alison Wallace
Ellen Brisch
Steve Dahlberg
Sheila Michaels
Shireen Alemadi
Chem-Biol Bridging
Meena Balgopal
Taé Nosaka
Karen Raines
Erik Arthur
Sam Desta

WTL Advisory Board
Mike Palmquist
Kate Kiefer
Sue Doe

Graduate Students
Aramati Casper
Jake Herman
Julie Walker
Peter Leipzig-Scott
Katie Boyd
Anna Keith

Undergraduate Students
Clayton Korson (CSU)
Molly Gareis (MSUM)
Phillip King (MSUM)
Chris Flores (MSUM)
Emily O’Meara (MSUM)

Funding
NSF TUES
CSU KEY/Provost
CSU TILT/Provost

Background → Example 1 → Example 2 → WTL → Summary

Summary

Active learning improve learning outcomes

Active learning activities involving gamification for large lecture classes

Increasing scientific literacy through WTL on socio-scientific issues

Questions? Comments?
How Do Your Students Study for Exams in Your Course?

What is learning?
formation of new synapses between neurons in your brain, strengthening or removal of connections (neural plasticity)

What is teaching?
creating conditions that promote these structural changes in our students’ brains

Comparison of fMRI data from passive listening and active-response story processing tasks

Learning on a cellular level:
We are shaped by our experiences

Martina Rosenberg
& Katie Southard
MWSI 2015
The Neurobiology of Learning and Memory: A Short Overview

INPUT
incoming info first processed

CONSOLIDATION
info moved into long term memory

STORAGE
★ build/strengthen networks of neurons

RETRIEVAL
you access the info when you need it

Background → Example 1 → Example 2 → WTL → Summary

Background → Example 1 → Example 2 → WTL → Summary

The Constructivist Approach to Teaching and Learning

• Information is added, restructured and integrated into existing knowledge by learners
• Active and dynamic process

Background → Example 1 → Example 2 → WTL → Summary

Key Points

• Learning for understanding entails placing information into a conceptual framework that will allow that information to be more useful to the student
• Teachers cannot simply “tell” students the overarching conceptual framework for information; they must help students make the connections

Background → Example 1 → Example 2 → WTL → Summary

Cognitive Psychology Science:

• Quality - better than quantity
• Elaborate – self-reference connections, examples, meaning
• Test self – practice, explain
• Spaced study – time in between practice/study sessions (vs. cramming)

Martina Rosenberg & Katie Southard
MWSI 2015

Background → Example 1 → Example 2 → WTL → Summary

Background → Example 1 → Example 2 → WTL → Summary

Background → Example 1 → Example 2 → WTL → Summary

Background → Example 1 → Example 2 → WTL → Summary

Background → Example 1 → Example 2 → WTL → Summary

Dr. Ed DeLosh, Psychology, CSU
Make It Stick

By Brown, Roediger and McDaniel

1. Retrieval practice while studying/practicing
2. Spaced study/practice – 1-2 days then 1 week
3. Interleave/interweave study/practice of different topics
4. Elaboration – connection to previous knowledge, explaining and applying
5. Generation – try answering questions or problems before covering the material (learning needs to feel hard)
6. Reflection (metacognition) – think about what covered, what you know, how it connects to previous knowledge while studying, what is important/detail, potential test questions
7. Calibration – testing and quizzing yourself
8. Mnemonic devices – mental filing systems
9. Difficulty during learning/study is good/better
10. Science abilities are not “genetic” or “hard-wired”