Case studies, problem-based learning, and other methods of engaging students

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Topics for today

- Why active learning?
  - Social constructivism
  - Importance of prior knowledge
- Active learning pedagogies
  - Case-based learning
  - Problem-based learning
  - Process-oriented guided inquiry learning

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Social constructivism

- **Constructivism**
  - Knowledge is constructed in the mind of the learner by the learner.

- **Social constructivism**
  - This process is enhanced in a socially cooperative environment.

“As the cognitive load increases, the need for student engagement increases.”

Importance of prior knowledge

- Prior knowledge plays a large part in what students will be able to learn in a given context.
- Students make sense of new ideas by connecting them to what they already know.
  - Misconceptions held by the students can be difficult to change.
  - Misconceptions persist, and can interfere with learning.
  - Good students can earn high grades without really understanding the material.
Importance of prior knowledge

- In the Harvard University/Smithsonian Minds of Our Own series, researchers show fourth-graders a seed and a log and ask them where the mass comes from.
  - Answer: Sun, soil, water.
- Researchers ask MIT graduates the same question.
  - Answer: Sun, soil, water.
- Students “learn” photosynthesis, but miss the main idea.
  - The misconception? Carbon dioxide has no mass.

DVD: Minds of Our Own—Into Thin Air, Harvard University/Smithsonian
Importance of prior knowledge

“[Physics education research]..has..established that (1) commonsense beliefs about motion and force are incompatible with Newtonian concepts..(2) conventional physics instruction produces little change in these beliefs, and (3) this result is independent of the instructor and the mode of instruction.”

The force concept inventory

- Designed by three physics instructors to probe student beliefs.
  - The central concept of Newtonian mechanics is force, so questions were written to test student knowledge of forces.
  - Without an understanding of force, students cannot understand mechanics.
- Students are given a series of multiple choice questions in which they need to choose between the correct Newtonian concept and commonsense beliefs.
- The test is not meant to test intelligence, but to serve as a means to identify commonly held misconceptions.
A study was conducted with students in 62 introductory physics courses enrolling 6542 students.

- Fourteen “traditional” (T) courses (n = 2084)
  - Little or no IE methods
  - Passive student lectures
  - Recipe labs
  - Algorithmic problem exams
- Forty-eight “interactive engagement” (IE) courses (n = 4458).
  - “Heads on” and “hands on” activities that yield immediate feedback through discussion with peers and/or instructors.
Using the force concept inventory

- Students took the 29-item multiple choice test on the first day and then again on the last day of the course.
- An average normalized gain, \( <g> \), for a course was calculated:

\[
<g> = \frac{\frac{\%<G>}{\%<G>_{\text{max}}}}{\left(100 - \frac{\%<S_i>}{\%<S_i>_{\text{max}}}\right)}
\]
Using the force concept inventory

\[
\langle g \rangle = \frac{\% \langle G \rangle}{\% \langle G \rangle_{\text{max}}} = \left( \frac{\% \langle S_f \rangle - \% \langle S_i \rangle}{100 - \% \langle S_i \rangle} \right)
\]

- “High g” courses have a \(<g>\) value greater than 0.7.
- “Medium g” courses have \(<g>\) values between 0.3 and 0.7
- “Low g” courses have \(<g>\) values less than 0.3
- IE courses are shown by open squares, circles or diamonds.
- T courses are shown by filled shapes.
All points for the fourteen “T” courses fall in the low $<g>$ region.

$<<g>>_{14T} = 0.23 \pm 0.04$
Seven of the 48 IE courses fall in the low-g region.

41 of the 48 IE courses fall in the medium-g region.

\[ \langle g \rangle_{48IE} = 0.48 \pm 0.14 \]
None of the courses fell in the high-$g$ region.
Using the force concept inventory

“Assuming, then, that <g> is a valid measure of course effectiveness in promoting conceptual understanding, it appears that the present interactive engagement courses are, on average, more than twice as effective in building basic concepts as traditional courses.”

Other concept inventories

- The Biological Concept Inventory (BCI) was developed by Garvin-Doxas and Klymkowsky.
- Students believe that biological processes are efficient and random processes are inefficient.
  - This misconception hampers understanding of biological processes from diffusion to evolution.

Imagine that you are an ADP molecule inside a bacterial cell. Which best describes how you would manage to “find” an ATP synthase so that you could become an ATP molecule?
The biochemistry concept inventory

A CONCEPT INVENTORY FOR MOLECULAR LIFE SCIENCES: HOW WILL IT HELP YOUR TEACHING PRACTICE?

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Why active learning in biochemistry?

- The Education and Professional Development Committee (EPD) of the American Society for Biochemistry and Molecular Biology (ASBMB) has prepared a list of skills that all students should have when they graduate with a degree in biochemistry.

http://www.faseb.org/asbmb/epd/Curriculum.html
Skills that biochemistry students should obtain

- Understanding of the key principles of biochemistry and molecular biology.
- Ability to dissect a problem.
- Ability to interpret experimental data.
- Awareness of how to use available resources.
- Ability to collaborate with other researchers.
- Ability to think in an integrated manner and look at problems from different perspectives.
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The “process vs. content” debate

- Core knowledge...
  - Boyer (*BAMBED* 28 (2000), pp. 292-296) has suggested a list of “core topics” that should be covered in an intro biochemistry course.
- Or core skills?
  - Ross Feldberg (*BAMBED* 29 (2001), pp. 222-224) suggests that instructors make up a skill set.
  - Then address how each topic contributes to the acquisition of that skill.
“Content” or “directed” case studies

- First described by physiologists Cliff and Wright (*Am. J. Physiol.* **270**: S19-S28 (1996))
  - They wrote clinical cases designed to teach students basic principles of anatomy and physiology.
  - The cases were built around very specific learning objectives, rather than being open-ended.
  - Questions are straightforward and emphasis is on information that is available to the student.
- The case study method is used as an alternative to the lecture to convey scientific content to the students.
  - Some instructors are reluctant to use the case study method because they feel that doing so would decrease the amount of coverage of the material.
Why use case studies in biochemistry?

“The difficulty of engaging learners in the processes and problems of science is most likely to occur in the first year courses dealing with fundamental topics, as the learners are not yet prepared to perceive the relationship between these topics and the practice of their careers.”

Types of biochemistry case studies

- Metabolic case studies
  - Inborn errors of metabolism
- Analysis of “real” scientific data
  - Taken from introductory biochemistry concepts found in the current literature
Directed case studies—resources

- *Cases in Biochemistry*, published in 1999 by John Wiley & Sons, has been updated and can be found on [my web site](#). The cases are also available on WileyPLUS.
- J. Szeberenyi regularly publishes these types of exercises in [BAMBED](#).
- Clyde Herreid and Nancy Schiller have compiled a bank of case studies developed at their annual case-writing workshops held at [University of Buffalo](#).
PBL vs subject-based learning

START

Given problem to illustrate how to use it

Told what we need to know

Learn it

PBL vs subject-based learning

1. Identify what we need to know
2. Learn it
3. Apply it

PBL: The process

Resolution of Problem; (How did we do?)
- Integrate new Information;
- Refine questions
- Reconvene, report on research;
- Research questions; summarize; analyze findings

Presentation of Problem
- Organize ideas and prior knowledge (What do we know?)
- Pose questions (What do we need to know?)
- Assign responsibility for questions; discuss resources

Next stage of the problem
A typical day in a PBL course

University of Delaware
PBL problems—resources

• Hal White has compiled a list of articles published in *Biochemistry and Molecular Biology Education* (formerly *Biochemical Education*) and has posted the citations on his web site.

• **PBL Clearinghouse** at University of Delaware.

• P. K. Rangachari of McMaster University has posted several of his case studies on his web site.
What is POGIL?

“Process Oriented Guided Inquiry Learning (POGIL) is a research-based learning environment where students are actively engaged in mastering course content and in developing essential skills by working in self-managed teams on guided inquiry activities”.

http://www.pogil.org
What is POGIL?

“In addition to learning, understanding, and applying new concepts, students ... develop... skills in the areas of information processing, critical thinking, problem solving, teamwork, communication, management, and assessment. The instructor ... guide[s] and question[s] the teams as they work through the specially designed activities.”

http://www.pogil.org
What is POGIL?
POGIL is a marriage of…

**Process Oriented**
- Cooperative learning

**Guided Inquiry**
- Constructivism

- Information Processing
- Critical Thinking
- Problem Solving
- Communication
- Teamwork
- Management
- Self-assessment

Loertscher and Minderhout, Seattle U.
“Concept Formation” activity

The Learning Cycle

Concept  Invention ➔ Exploration ➔ Application

• The concepts to be understood are explicitly presented in the Model.
• Key Questions reinforce understanding of presented concepts and develop process skills.
Developing materials

- The activity begins with a **model** that is used to develop 1-3 key concepts.
  - Key questions guide students to explore desired concepts.
- The students solve exercises, problems, or critical thinking questions in order to apply the concepts learned in the model.
- Specific process skill development takes place in the context of the activity.
Models in biochemistry

- Any figure from the textbook
  - Mechanism
  - Pathway
  - Protein structure
- A graph
- An equation
- A patient
  - Drug overdose
  - Inborn error of metabolism
- A scientific paper
Available materials

- Published materials are available in general, GOB, organic, analytical and physical chemistry.
  - University and high school levels.
- Materials are also available in biology.
- Materials are being developed by the POGIL Biochemistry Core Collaborators group.
  - Vicky Minderhout and Jenny Loertscher at Seattle University are the leaders of this group.
- Samples available at www.pogil.org.
“Model” resources

Conclusion

“Perhaps the entire conference [PBL 2002] could be summarized by this statement from Ed Wood’s paper presentation: “PBL encourages active learning and the development of higher order thinking skills, so why don’t we just get on with it?”

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