The One Who Does the Work Does The Learning

Mark Decker, Ph.D.
Associate Department Head
Department of Biology Teaching and Learning
University of Minnesota
### Introduction to student-centered guided inquiries: Examples

- Example of a guided inquiry:
  - “Balls and sticks” guided inquiry
  - Debrief guided inquiry

### Why teach this way?

- What the research says
- Bloom’s taxonomy, formative assessment, and metacognition

### Creating student-centered, active-learning environments

- Backward design principles
- You can do it!: A structured approach to building guided inquiries

### Moving forward

- Best practices
- Overcoming obstacles
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Bloom's Taxonomy uses a multi-tiered scale to express levels of expertise in content knowledge.

- **Knowledge**: memorize
- **Understanding**: summarize
- **Application**: solve problems
- **Analysis**: evaluate logic
- **Synthesis**: combine knowledge
- **Evaluation**: make decisions
Foundations of Biology
BIOL 2002, 2003, 2004

Instead of lecture ... what? CONCEPT LAB

- Independent learning
  - Study guides
  - Textbook
  - Web-based resources
  - Self-quizzes

- Learning readiness quizzes
  - Individual quiz
  - Team quiz

- Application & analysis activities
  - Problems
  - Simulations
  - Case studies
  - Data analysis
  - Models
  - Discussion

- Synthesis & evaluation activities
  - Annotated outlines
  - Research abstract
  - Poster
  - Oral presentation
  - Take-home exams
Biology 1003 (Section 040): Evolution and Biology of Sex  
Spring 2014

Science is a lot like sex.  
Sometimes something useful comes of it,  
but that's not the reason we're doing it.  
-- Richard Feynman

Meeting time & location:  T / Th, 1:00 - 2:15 p.m., 114 Science Teaching & Student Services Building  
Instructor:  Mark Decker, Ph.D, 223 Snyder (St. Paul), decker@umn.edu, 612-626-2038  
Office hours: Tuesdays, 3:00-4:00 p.m., 3-149B MCB; and by appointment  
Materials:  Red Queen: Sex & The Evolution Of Human Nature (M. Ridley)  
Biology 1003 Laboratory Manual  
iClicker  
Course site:  https://netfiles.umn.edu/users/decker/1003/

BIOL 1003 is a 4-credit introductory biology course intended for non-biology majors satisfying the liberal education requirements for a biology course with lab. This course has no prerequisites.

Welcome to BIOL 1003. The topics covered in this course have been chosen to build a strong foundation for understanding biology within the framework of the evolution and biology of sex. The major general goals of the course are to help you:

- build a framework of knowledge within the major themes of the course.  
- view biology as a set of organizing themes to better understand the unity and diversity of nature.  
- identify and understand ways that biology directly affects your life.

I feel strongly that the concepts covered in BIOL 1003 contribute in an important way to a well-rounded university education and hope that everyone succeeds in this course (and I will be happy -- ecstatic! -- to award all “A” grades, if warranted).

You are responsible for knowing and abiding by the following policies.

Main office (Biology Program): Administration of BIOL 1003 is handled by the Biology Program, 3-154 Molecular and Cellular Biology, 420 Washington Ave. SE, 612-625-2532. Questions about course content and grades, however, should be directed toward your lecture or lab instructor, as appropriate.
Huxley therefore introduced the term *epigamic* to apply to characters...
Components of sexual selection:

1. **Intrasexual selection**
   ("Male-male competition")

2. **Intersexual selection**
   ("Female choice")
Bloom's Taxonomy of Learning Objectives

- **Knowledge**: memorize
- **Understanding**: summarize
- **Application**: solve problems
- **Analysis**: evaluate logic
- **Synthesis**: combine knowledge
- **Evaluation**: make decisions
1. A central goal of classification of organisms based on their evolutionary history is to create taxa (e.g., genera, families, orders, etc.) that
A. group together as much diversity as possible.
B. contain single species.
C. include taxa that are all descended from a common ancestor.
D. group organisms based on similarity due to convergent evolution.

2. A trait (character state) shared among a group of taxa but where the identity/similarity of the trait is not due to common ancestry is known as
A. homoplasy.
B. homozygosity.
C. homospory.
D. homology.

3. A phylogeny is the
A. life history of an organism.
B. branch of biology concerned with the relationship between vegetation and the amount of rainfall.
C. evolutionary history of a group of organisms.
D. branch of biology concerned with the relationship between plants and animals.

4. If life on Earth is monophyletic, this means that all life on the planet is
A. constantly evolving due to natural selection.
B. derived from a single common ancestor.
C. based on cells.
D. destined to go extinct.

5. To reconstruct the evolutionary history among a group of taxa, similarities and differences among taxa can be used?
A. morphological
B. anatomical
C. genetic
D. All of the above

6. Given to the right is a phylogenetic tree that shows the hypothesized relationships among the six kingdoms into which life can be classified. If this tree is the true evolutionary history for these taxa, and based only on the information presented in this tree, which of the following statements is/are TRUE?
I. Archaebacteria are more closely related to fungi than to any other kingdom.
II. Animals are more closely related to plants than to any other kingdom.
III. Fungi are more closely related to animals than to any other kingdom.

The correct statements are:
A. I only
B. II only
C. III only
D. I and II only
E. I, II, and III
What's the point?
Bloom's Taxonomy of Learning Objectives

- **Knowledge**: memorize
- **Understanding**: summarize
- **Application**: solve problems
- **Analysis**: evaluate logic
- **Synthesis**: combine knowledge
- **Evaluation**: make decisions
• Size of male symbol represents male body size relative to females body size (female symbol) for each species.
• Arrows on male symbols are proportional penis length for each species.
• Twin circles are proportional size of testicles for each species.

In teams, 5 minutes:
On your whiteboards, list differences/similarities you see among this group of closely related primates?
In teams, 5 minutes:

On your whiteboards, generate hypotheses to explain these observed differences/similarities?

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*In teams, 3 minutes:*

Rotate to the whiteboard of the next highest-numbered team (Team 19 go to Team 1) and evaluate that team’s hypotheses.

Bloom's Taxonomy of Learning Objectives

Knowledge
- memorize

Understanding
- summarize

Application
- solve problems

Analysis
- evaluate logic

Synthesis
- combine knowledge

Evaluation
- make decisions
In teams:

If:

1. suitable sites for nests are in limited supply

and

2. a young (i.e., small) male may not be competitive for a nest site,

what adaptive traits might young males exhibit to increase their reproductive output when they are young?
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Moving forward

- Best practices
- Overcoming obstacles
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In teams, 2 minutes:
Discuss what is intended to be accomplished by this inquiry activity?

What’s the point?
Active learning

A process in which students are actively engaged in learning (e.g., inquiry-based learning, cooperative learning, student-centered learning).
MAKING MEMORIES STICK

Some moments become lasting recollections while others just begin with.

BY R. DOUGLAS

In the movie thriller *Memento*, the principal character, Leonard, can remember everything that happened before his head injury on the night his wife was attacked, but anyone he meets or anything he has done since that fateful night simply vanishes. He has lost the ability to convert short-term memory into long-term memory. Leonard is driven to find his wife’s killer and avenge her death, but trapped permanently in the present, he constantly remains the dregs of his investigation. Such patients are the focus of the science of memory, as the book title suggests.

*The Science of Successful Learning*

Peter C. Brown
Henry L. Roediger III
Mark A. McDaniel
Learning results from what the student does and thinks, and only from what the student does and thinks.

Herbert Simon (1916-2001)  
Nobel Prize in Economics, 1978

“The One Who Does the Work Does the Learning”
Kolb’s Learning Cycle

Motor (Testing)

Sensory (Experience)

Integrative (Abstraction)

Meaning (Reflection)
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In teams, 5 minutes:

On your whiteboards, list as many reasons as you can for building learning environments that stress active engagement by students.
**Introduction to student-centered guided inquiries: Examples**

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**Creating student-centered, active-learning environments**

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**Moving forward**

- Best practices
- Overcoming obstacles
Active learning enhances content knowledge

Table 3. A comparison of final performance in the active and traditional sections of Biology 1001

<table>
<thead>
<tr>
<th></th>
<th>Traditional (n = 240)</th>
<th>Active (n = 263)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean final percentage</td>
<td>71.5%</td>
<td>74.7%</td>
</tr>
<tr>
<td>SD</td>
<td>15.34</td>
<td>10.89</td>
</tr>
<tr>
<td>Skewness</td>
<td>-1.48</td>
<td>-0.81</td>
</tr>
<tr>
<td>Percentage of grades below 40%</td>
<td>4.5</td>
<td>0.4</td>
</tr>
</tbody>
</table>
Active learning enhances critical thinking skills

Article

Improvement in Generic Problem-Solving Abilities of Students by Use of Tutor-less Problem-Based Learning in a Large Classroom Setting

Andis Klegeris,* Manpreet Bahniwal,* and Heather Hurren†

*Department of Biology and †Centre for Teaching and Learning, University of British Columbia, Okanagan Campus, Kelowna, BC V1W 1V7, Canada

Problem-based learning (PBL) was originally introduced in medical education programs as a form of small-group learning, but its use has now spread to large undergraduate classrooms in various other disciplines. Introduction of new teaching techniques, including PBL-based methods, needs to be justified by demonstrating the benefits of such techniques over classical teaching styles. Previously, we demonstrated that introduction of tutor-less PBL in a large third-year biochemistry undergraduate class increased student satisfaction and attendance. The current study assessed the generic problem-solving abilities of students from the same class at the beginning and end of the term, and compared student scores with similar data obtained in three classes not using PBL. Two generic problem-solving tests of equal difficulty were administered such that students took different tests at the beginning and the end of the term. Blinded marking showed a statistically significant 13% increase in the test scores of the biochemistry students exposed to PBL, while no trend toward significant change in scores was observed in any of the control groups not using PBL. Our study is among the first to demonstrate that use of tutor-less PBL in a large classroom leads to statistically significant improvement in generic problem-solving skills of students.

INTRODUCTION

Problem-based learning (PBL) has its roots in medical education programs but is now being used in a wide variety of disciplines. The method is based on the premise that learning is most effective when students are engaged in solving problems that are relevant to their interests and goals. PBL is the implementation of contextualized problems, which enable students to develop problem-solving skills in addition to acquiring subject-specific knowledge (Jonassen, 2011). The majority of research on the effectiveness of PBL is focused
Active learning enhances student engagement & satisfaction

Active Learning and Student-centered Pedagogy Improve Student Attitudes and Performance in Introductory Biology

Peter Armbruster,* Maya Patel,†† Erika Johnson,* and Martha Weiss*

We describe the development and implementation of an instructional design that focused on bringing multiple forms of active learning and student-centered pedagogies to a one-semester, undergraduate introductory biology course for both majors and nonmajors. Our course redesign consisted of three major elements: 1) reordering the presentation of the course content in an attempt to teach specific content within the context of broad conceptual themes, 2) incorporating active and problem-based learning into every lecture, and 3) adopting strategies to create a more student-centered learning environment. Assessment of our instructional design consisted of a student survey and comparison of final exam performance across 3 years—1 year before our course redesign was implemented (2006) and during two successive years of implementation (2007 and 2008). The course restructuring led to significant improvement of self-reported student engagement and satisfaction and increased academic performance. We discuss the successes and ongoing challenges of our course restructuring and consider issues relevant to institutional change.

INTRODUCTION

The traditional lecture format of most large introductory science courses presents many challenges to both teaching and learning. Although a traditional lecture course may be effective for efficiently disseminating a large body of content to a large number of students, these one-way exchanges often promote passive and superficial learning (Bresnahan et al. 1998; NRC, 1999, 2003, 2007; Handelsman et al., 2004, 2007; Project Kaleidoscope, 2006). This need is particularly acute at the introductory level, where a major “leak in the pipeline” toward science careers has been noted (Seymour and Hewett, 1998; Seymour, 2001; NRC, 2007).

Although the proposed improvements noted above differ in detail, a remarkably consistent theme is the call to bring increased participation (Engle et al., 1986; Ciurli and Jerald, 1991; Linn et al., 2001). This feature allows students to combine the principles of learning that emphasize immediate engagement, student-centeredness, and active participation (Matsui et al., 2003; Dillenbourg et al., 2002; Aiken et al., 2001; Rasmussen et al., 1998; NRC, 1999, 2003, 2007; Handelsman et al., 2004, 2007; Project Kaleidoscope, 2006).
Active learning works!

Active learning increases student performance in science, engineering, and mathematics.

The effect sizes indicate that on average, student performance on examinations and concept inventories increased by 0.47 SDs under active learning \((n = 158\) studies), and that the odds ratio for failing was 1.95 under traditional lecturing \((n = 67\) studies). These results indicate that average examination scores improved by about 6% in active learning sections, and that students in classes with traditional lecturing were 1.5 times more likely to fail than were students in classes with active learning.

Although traditional lecturing has dominated undergraduate instruction for most of a millennium and continues to have strong advocates, current evidence suggests that a constructivist “ask, don’t tell” approach may lead to strong increases in student performance.

The results raise questions about the continued use of traditional lecturing as a control in research studies...
Expected vs. Actual Grades (BIOL 1003), Traditional vs. ALC

<table>
<thead>
<tr>
<th></th>
<th>Expected</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Traditional</strong></td>
<td>78.52%</td>
<td>77.77%</td>
</tr>
<tr>
<td><strong>ALC</strong>**</td>
<td>71.77%</td>
<td>76.49%</td>
</tr>
</tbody>
</table>
Grades on assignments

- Participation: 96.7%
- Financial Planner: 92.4%
- Case Studies: 90.9%
- Final Exam: 91.3%
- Aggregated Quizzes: 91.3%

Legend:
- Active Learning
- Lecture
Effect of introductory biology course on performance in BIOL 4003 (Genetics)

Course grade: BIOL 1001 + 1002 (lecture) vs. BIOL 2002 + 2003 (active learning)

Frequency (%)

$p < 0.01$
Activities and Instructor Behaviors

- Lecture: ALC 74.1%, Traditional 69.3%
- Discussion: ALC 4.7%, Traditional 2.1%
- Group Activity*: ALC 43.2%, Traditional 32.6%
- Q&A: ALC 35.9%, Traditional 40.4%
- At Podium**: ALC 82.2%, Traditional 89.0%
- Not at Podium***: ALC 75.0%, Traditional 89.0%
- Consulting**: ALC 26.7%, Traditional 14.6%
- Not Consulting: ALC 95.8%, Traditional 97.4%

* ALCS: Active Learning Classrooms
** Traditional
*** ALCS: Active Learning Classrooms

ALC: Active Learning Classrooms
Traditional
Activities and Instructor Behaviors
Science Teaching and Student Services Building
Collaborative teams are formed purposefully by instructors:

1. Sex ratio is ~balanced.

2. International students are never isolated in teams (i.e., at least paired up with another international student).

3. Transfer students are never isolated in teams.

4. Overall team composition is determined by creating a mix of personality types using self-response data from an online survey that students complete prior to start of the term.

Students remain in same teams throughout the term.

Teams are given considerable coaching on how to manage team dynamics and provide/accept peer evaluation.
In teams, 2 minutes

How will learning in this environment ...

be different from... learning in this environment?
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- Backward design principles
- You can do it!: A structured approach to building guided inquiries

Moving forward

- Best practices
- Overcoming obstacles
Bloom's Taxonomy of Learning Objectives

- Knowledge: memorize
- Understanding: summarize
- Application: solve problems
- Analysis: evaluate logic
- Synthesis: combine knowledge
- Evaluation: make decisions
Instead of lecture ... what? **CONCEPT LAB**

- **Independent learning**
  - Study guides
  - Textbook
  - Web-based resources
  - Self-quizzes

- **Learning readiness quizzes**
  - Individual quiz
  - Team quiz

- **Application & analysis activities**
  - Problems
  - Simulations
  - Case studies
  - Data analysis
  - Models
  - Discussion

- **Synthesis & evaluation activities**
  - Annotated outlines
  - Research abstract
  - Poster
  - Oral presentation
  - Take-home exams
Formative assessment

The goal of formative assessment is to allow students (and instructors) to monitor their learning so as to provide ongoing feedback to improve their learning. Formative assessments:

- help students identify their strengths and weaknesses and target areas that need work
- help faculty recognize where students are struggling and address problems immediately

Formative assessments are generally low stakes, which means that they have low or no point value.
Metacognition

**Metacognition refers to** one’s knowledge concerning one’s own cognitive processes **or anything related to them,** e.g., the learning-relevant properties of information or data.

For example, I am engaging in metacognition if I notice that I **am having more trouble learning A than B;** if it strikes me that I **should double check C before accepting it as fact.**

(Flavell, 1976)

The goal of including metacognition in the learning process is to develop
- **reflective**
- **self-motivated**
- **self-regulated** learners.
**Metacognition 10**

What did I learn this week that improved my knowledge of biology?

What did I learn about being a biologist?

What questions do I still have?

What did I do this week that helped improve my abilities in the following learning outcome areas?

- Understand and apply scientific reasoning and process
- Use technology effectively to obtain and evaluate information
- Communicate effectively in a scientific context
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BACKWARD DESIGN
Principles of backward design in teaching

1. Identify your learning goals for the students
2. Identify your learning objectives for the students
3. Identify what assessment will be used to measure attainment of these learning objectives
4. Create a **learning experience** for students to achieve these learning objectives
• Size of male symbol represents male body size relative to females body size (female symbol) for each species.
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Principles of backward design in teaching

1. Identify your learning goals for the students
Learning goals

1. Understand what sexual selection is and what kind of traits it affects.

2. Understand that there are different determinants for male and female reproductive success (output).

3. Understand that sexual selection may therefore promote very different reproductive strategies in males and females.

4. Appreciate that evolutionary biology is an experimental, data-driven science.
Principles of backward design in teaching

1. Identify your learning goals for the students

2. Identify your learning objectives for the students
Learning objectives

1. Be able to interpret the figure from Bateman (1948) as the basis for fundamental differences in determinants of reproductive success.

2. Be able to provide a hypothesis for how a distinctive reproductive trait in one sex could be the product of sexual selection.

3. Be able to design an experiment to test your hypothesis.

4. Be able to interpret data relevant to your hypothesis and proposed experiment.
Principles of backward design in teaching

1. Identify your learning goals for the students
2. Identify your learning objectives for the students
3. Identify what assessment will be used to measure attainment of these learning objectives
Assessment

1. Team-based discussion of inquiry activity (formative)

2. Instructor-led class-wide discussion of inquiry activity (formative)
Assessment

1. Team-based discussion of inquiry activity (formative)

2. Instructor-led class-wide discussion of inquiry activity (formative)

3. Challenge questions (done independently or in teams) that mirror what exam questions will ask (formative)
Challenge Question

Interpret and explain these data from Gomendio & Roldan (1991) relative to sexual selection theory.
Assessment

1. Team-based discussion of inquiry activity (formative)

2. Instructor-led class-wide discussion of inquiry activity (formative)

3. Challenge questions (done independently or in teams) that mirror what exam questions will ask (formative)

4. Exam question which requires creation of hypothesis, experimental design, and data interpretation for a trait that is the result of sexual selection (summative)
1. It is often assumed that the timing of ovulation in women is hidden even from themselves. For example, behavioral ecologist Nancy Burley stated in 1979 that “among humans, ovulation is neither perceived consciously by others nor by self.” Numerous explanations have been developed for the selective advantage of concealed ovulation including:
   - a reduction in male competition and aggression, which in turn results in more cohesive, cooperative social units
   - promotion of continual sexual receptivity, which could function to increase the strength of bonds between mates
   - that females are essentially tricking males into long-term commitments, because males cannot be sure that one or a few copulations are sufficient to result in pregnancy

All of these arguments, however, fail to acknowledge that there may be selection operating on men to be able to detect what part of the ovulatory cycle a woman is in.

a. Discuss why there would be a fitness advantage to men of being able to determine the ovulatory state of women.

b. The data to the right are from a study by Miller et al. 2007 that examined the amount of money earned as tips by female lap dancers in relation to phase of their ovulatory cycle.

Interpret these data relative to 1) the supposed hidden nature of ovulation in humans, and 2) your discussion in Part a above.
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<table>
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<tr>
<th>Overview of activity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Title of activity:</strong></td>
</tr>
<tr>
<td><strong>Context:</strong> Student population / course the activity is designed for.</td>
</tr>
<tr>
<td><strong>Summary of activity:</strong></td>
</tr>
<tr>
<td><strong>Learning goals:</strong> What will students understand after finishing the activity?</td>
</tr>
<tr>
<td>1.</td>
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<td>6.</td>
</tr>
<tr>
<td>7.</td>
</tr>
<tr>
<td><strong>Learning objectives:</strong> What will students be able to do after finishing the activity?</td>
</tr>
<tr>
<td>1.</td>
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<td>2.</td>
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<td>3.</td>
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Do you need to go all in?
Management for the Active Classroom

- Start simple
- Start early
- Make it personal
- Take risks
- Give positive feedback
- Deal with “wrong”
- Maintain control and high standards
- Stress ethics of group work
- Design the classroom to be inclusive
- Design the out-of-class experience to be inclusive
Personal perspectives

• It’s OK to start small (“evolutionary vs. revolutionary”)
• Build on what you already have
• Don’t succumb to the allure of technology: low-tech approaches often work just fine
• Provide repeated mapping of what is being done to the learning objectives
• Create opportunities for formative assessment
• Provide coaching/mentoring to students on ethics and dynamics of group work (and opportunity to practice evaluating others’ work and efforts)
• Have colleagues evaluate what you’re doing in the classroom; visit others’ classrooms; teach in teams
• Be transparent with students
• Be adaptable and willing to say “I don’t know”