Studio Biology For Engineers: Lessons Learned

Dr. Christopher Josh Ramey, Colorado School of Mines

Teaching Assistant Professor at Colorado School of Mines. Interested in developing active learning experiences and undergraduate research programs. Educational background in molecular biology with emphasis in genetic engineering.

Dr. Judy Schoonmaker, Colorado School of Mines
Sarah M. Ryan, Colorado School of Mines
Making the Change from Lecture to an Active Learning Environment: Lessons Learned
Abstract

We recently transformed a traditional introductory biology course into an active learning experience that resonates with a wide range of undergraduate students. Backward course design led to an innovative curriculum that (1) is based on biology’s big ideas, (2) has measurable learning outcomes, and (3) encourages development of higher order thinking skills. Our studio classroom design maximizes interactions; cantilevered workstations distributed throughout the room encourage student-instructor and student-student interactions. Group discussions occur at whiteboards as students solve problems, create concept maps, plan experiments and interpret experimental data. Workstation computers and dual monitors support whole-class instruction as well as student-led group explorations. The classroom design meets the traditional needs of a biology lab, including access to sinks, use of compound microscopes, data acquisition, gel electrophoresis and thermal cyclers. This creative new learning space supports a constructivist approach to learning, moving student conversations past rote repetition of textbook material to evaluation and synthesis of ideas, as well as dialogue about how science generates new information and the interface between biology and engineering. In the interest of helping others along their path toward implementing active learning in their classrooms, we share a description of our course transformation and important lessons learned in the process.

“Active learning should be the central dogma of science education”(Freeman et al., 2014). A growing body of data supports the conclusion that active learning is indeed superior to the traditional lecture format, both in terms of student retention and student performance (Natl.Acad.Sci, 2009; AAAS, 2011; PCAST, 2012; Singer, 2012). Recent efforts at Colorado School of Mines to integrate biology into our engineering curriculum have led to a revised foundational biology course that has rigor and relevance for our engineering students. The move from traditional lecture to an active learning environment was key in our efforts to engage our students, with the intent of improving our students’ comprehension of biology. Our course re-design involved a three-pronged approach in which we: (1) renovated a classroom to create a studio environment with wet-lab capability; (2) implemented a constructivist pedagogy and (3) designed a training program to develop teaching assistants (TAs) who could support a student-centered learning experience. We affirm that change is difficult, time-consuming, and expensive. However, our new studio biology classroom and course have helped our campus respond to the call for change in undergraduate biology education (AAAS, 2011) with the implementation of innovative pedagogy and creative new learning spaces. In this essay, we offer a description of this course transformation and several lessons learned from the process. We hope that our experiences can help others in their efforts to achieve more effective teaching and learning in undergraduate biology education and build connections to traditional engineering disciplines.

Characteristics of an Active Learning Space

We had an opportunity to design an active learning environment when our department acquired a traditional lab space that was in serious need of renovation (Figure 1A). Taking inspiration from the success of an active-learning physics course on our campus (Kohl and Kuo, 2012), we developed a unique student-centered design for our biology classroom (Figure 1B). Several characteristics of this space support active learning. (1) The studio environment maximizes interactions: Each pod (Figure 2) seats nine students distributed among three workstations that
radiate out from a central hub. At each workstation, three students face each other. The cantilevered island eliminates table legs and provides knee space for three (Figure 2). Working within the constraints of the pre-existing room, we have found it fortuitous that the L-shaped design (Figure 3) has few direct sight lines and thus encourages instructors to limit lectures. Whiteboards along the room perimeter provide a venue for discussion among students as they design experiments, build concept maps and illustrate biological processes. Lab materials, group reagents and equipment are available for pick-up cafeteria-style at a centralized location in the classroom. (2) The studio classroom allows whole class instruction that is enhanced by technology. Our studio environment integrates technology into the course, allowing students to explore current topics in biology and discuss how science generates new information. To support whole class instruction, a variety of signals from the instructor’s podium can be displayed on the upper monitor at each workstation (Figure 2). This signal can be from a ceiling-mounted document camera, a microscope with a digital camera, a personal computer or the podium computer. A local workstation computer and monitor (Figure 2) provide student access to the internet, instructional content on a course management system (e.g., Blackboard), and data acquisition software (e.g., LoggerPro3 by Vernier) for use during labs. (3) The studio classroom provides wet lab capability at each workstation: The classroom design meets the traditional needs of a biology lab. Student groups have ready access to micropipettors, a digital balance, stirring hot plate, compound light microscope, sink and storage in overhead bins.

Course Structure and Pedagogy

In developing an active learning experience for our students, a redesign of the structure and pedagogy of our course was perhaps more important than the changes we made to the physical environment. To this end, we employed backwards course design to develop a streamlined curriculum grounded in scientific teaching, which promotes inclusive excellence, assessment, and active learning (Handelsman et al., 2004; Couch et al., 2015). Our design goals were to (1) explore the fundamental concepts of biology using active learning strategies and open inquiry labs, (2) incorporate measurable learning outcomes into activities and assessments and (3) encourage development of higher order thinking skills using Bloom’s taxonomy (Crowe, Dirks, and Wenderoth, 2008). There are six contact hours per week (4 credit hours), distributed as either three-hour blocks or two three-hour blocks. To increase the depth of learning, we reduced the scope of our studio course from that of a lecture-based survey course to four main topics: the chemistry of life, cell structure and processes, gene structure and expression, and biotechnology.

The hierarchical Biology Concept Framework, developed by the Walker Education Group at MIT, (Khodor et al., 2004) provided the basis for our course learning goals, learning outcomes and assessments. These learning goals and outcomes are the foundation of the course; we put into practice the adage “tell them what you’re going to tell them, tell them, then tell them what you told them.” Each reading assignment is paired with a study guide and thirty-minute online homework assignment that are directly related to the learning outcomes. The learning outcomes are repeatedly emphasized in all activities throughout the semester, as students move from initial discussions of a topic, to activities that encourage in-depth exploration, and finally, to exam reviews. In this way, students are given a scaffold on which to organize and connect new biological information as well as a framework for study prior to an exam. Students are expected to arrive prepared to engage with the material during in-class discussions and labs. Class begins
with a quick check (ten to fifteen minutes) for understanding of the assigned reading. Throughout these first crucial minutes of each class period, small student groups struggle with questions on big topics or common misconceptions, using textbooks and prepared study guides. This “productive confusion” leads to a list of questions, which are addressed by the instructor or TA with individual group tutorials or with a mini-lecture to the entire class. We limit this “just-in-time” teaching to fifteen to twenty minutes; by restricting the lecture to the muddiest points, we optimize the students’ interest and attention span. Next, a five-question concept clicker quiz is given to confirm a baseline understanding of the assigned reading (Smith et al., 2009; Miller and Tanner, 2015) and, importantly, to expose remaining misconceptions. A pivotal part of this formative assessment is the follow-up peer instruction associated with any quiz questions for which there is not a group consensus on the correct answer (Tanner and Allen, 2004). This pursuant discussion not only helps students who are struggling, but also allows students who better comprehend the material to cement their understanding by explaining the concepts to their peers (Cortright et al., 2005; Tanner, 2009b).

Group activities, termed Explorations in our course, emphasize enduring understanding over factual knowledge and process over details. Explorations (lasting one to two hours) use real-world examples and are designed to encourage students to apply baseline textbook information to novel problems (see example teaching unit in Figures 4 and 5). Explorations focus on a student’s ability to obtain and work with new knowledge, to think analytically, and to solve problems creatively. We task students to evaluate and analyze how foundational principles of biology are applied in relevant technology, design and legislation. Every effort is made to help learning be hands-on. We use models and manipulatives as well as activities that foster student interactions with their peers and professors (AAAS, 2011). At the end of class, students are given time to enhance their learning through metacognition (Mynlieff et al., 2014). Students are held accountable for their learning during each exploration by completing a series of follow-up questions stressing the key concepts. This exit ticket asks students to record three things they learned that day as well as three questions that they still have about the topic of the day. These tools give immediate feedback to the instructor about the learning that occurred during that day’s activities.

Skills Developed in a Studio Classroom

In addition to gaining a basic understanding of biology, our students are learning how to learn. From the start of the semester, we provide an environment where struggle is okay, and questions are encouraged. Students learn how to access resources and assess their quality. Students learn how to lead and be led, as their roles during group activities vary each week. In-class Explorations and case studies present students with challenging context-rich problems that require teamwork, communication, and time management. The weekly laboratory exercise is an integral part of our curriculum. Over the course of the semester, students conduct nine laboratory experiments that emphasize experimental design. For each one, a guided inquiry portion introduces the experimental setting under standard conditions. Students then discuss the baseline data and choose a question to investigate. An experimental design is developed, critiqued by a TA, adjustments are made, and the experiment is carried out. Because our classroom and lab are integrated, the spirit of discovery carries over from labs to discussions and Explorations. Our labs develop the foundational laboratory skills characteristic of many introductory biology
courses, including micropipetting, microscopy, spectrophotometry, cell culture, bacterial transformation, PCR, restriction digest, and DNA gel electrophoresis.

Lessons Learned: As we reflect on our first few years, we find that we have successfully transitioned from a large lecture course to an active learning environment. Additionally, we have extended the studio concept to two downstream courses: Biology II and Physiology. The change required significant activation energy and sustained effort as well as the considerable support of our institution. Our involvement in the National Academies of Science Mountain West Summer Institute, the American Academy of Colleges and Universities Project Kaleidoscope and our institutional framework of Engineering Learning (Figure 6) were key to moving forward. In these settings, we found supportive colleagues with similar pedagogical philosophies who validated our desire to change and offered many concrete ideas for achieving that change. Further, the excellent series of essays titled Transformations (Allen and Tanner, 2009) has served as an outstanding resource, with guideposts and specific examples of how to move one’s pedagogy toward active learning. We heartily acknowledge that change is an ongoing process. While we have implemented physical design changes to the classroom and we have laid the groundwork for student-centered learning in this course, there is still room for improvement. In that light, we offer several lessons learned for those setting out on a similar journey.

Lesson 1. Just do it! “Do what you can, with what you have, where you are.” (Theodore Roosevelt) From conversations with colleagues, it is clear that making the move from lecture to a constructivist classroom brings concerns about expenses and a legitimate fear of failure. To those who are hesitant to change, we would say, “keep it simple.” Add a “think-pair-share” activity to a lecture or use clickers to poll students for understanding. Try mobile seating in your classroom. Display a topic sentence from an assigned reading and ask students to explain it using their own words. Invite students to narrate a figure that illustrates an important process. Introduce concept mapping as a tool for students to organize ideas. The impact of these quick changes can be significant (Allen and Tanner, 2009).

We had the unique opportunity to pair our pedagogical changes with architectural changes. As an encouragement to others as they consider such a change, it should be noted that we were able to accomplish this change in just one academic year. We moved from committee discussions to a pilot class with mock-up plywood workstations in one semester. The following semester, our conversations with an architect culminated in a two-month summer renovation project before opening our studio classroom to our inaugural class in the fall.

Regardless of the scope of change, don’t reinvent the wheel; start where you are. During our pilot class, we reformatted existing lectures into a series of study guide questions. We have adopted many activities from other educators (see Table 1), blending them to create a unique presentation of ideas tailored for our students. To achieve success, one must adopt a growth mentality and be willing to fail. First efforts to do something new are often rough at best, but good teaching is iterative. Find the mental space for reflection; make notes and document changes right after an activity has been completed. It will not be perfect the first time. By demonstrating that as instructors we too can learn and improve, we model this behavior for our students. As difficult as it is to make mistakes publically, one must learn to be a functional perfectionist.
Lesson 2: Define and clearly communicate your goals. Our course is grounded in the tenets of scientific teaching and engineered learning. Thus, our course has clearly defined learning goals and measurable learning outcomes that are paired with assessments and classroom activities designed to engage a diversity of students (Handelsman et al., 2004; Couch et al., 2015). For each activity, we explicitly state the learning goals and expected student outcomes. We cannot underestimate the importance of stating these learning goals at every opportunity, as this helps students focus on the important concepts and promotes an enduring understanding of the material. Learning outcomes are driven by our learning goals; these outcomes provide a specific, action-oriented description of what each student should be able to do.

It is important for students to understand the benefits of active learning in terms of their own success. Students generally have a preconceived notion that their college courses will be lecture classes. To help students transition effectively, we carefully introduce active learning as a style of teaching early in the semester. We help students relate to the benefits of active learning by pointing out their prior experiences in pursuits such as playing sports, learning to play a new instrument or learning a new language. We present statistics about learning gains in the studio environment compared to a lecture class and detail the types of activities in which students can expect to participate (Freeman, 2014; Hake, 1998). We have observed that if students understand the benefits of active learning in terms of their own success, they are more willing to do their part to arrive prepared for and to participate in a healthy discussion during class.

Lesson 3: What matters most is who you’re teaching. The majority of our students are incoming freshmen in engineering and science. Even very bright college freshman must often improve their study skills to meet the demands of rigorous college courses. Early in the semester, we guide students toward an understanding their individual learning styles (Felder and Silverman, 1988). We have developed a wide range of activities to appeal to many learning modalities (examples provided in Figure 7). Students also discuss strengths-based leadership and the diversity of skills within their peer group. We illustrate this idea using the Four Domains of Leadership Strength (Rath and Conchie, 2008) and point out to our students that by celebrating their strengths, they can develop highly functional teams that overcome their individual weaknesses. Further, we implement best practices, making evidence-based adjustments to our teaching. We model being receptive to constructive criticism by checking with students after each unit to see what is or is not effective for their learning. We routinely use this student feedback to tweak activities and improve the course. In this way, we generate a classroom environment in which students feel they are part of the discussion and understand that their input matters.

We help students see that the skills developed in an active learning environment are remarkably similar to the life skills that many of them hope to develop during their college careers: initiative and self-directed growth, critical thinking and creative problem solving, communication, leadership and collaboration skills, information and technology literacy, and global awareness. Importantly, we put biology into a meaningful context for our engineering students. Students become more engaged when they can see the possible applications of the knowledge they are obtaining.
Lesson 4: Change requires trust and good leadership. It is important to build a classroom community culture that celebrates learning and inclusive excellence. Student confidence is a fragile thing. Learning how to engage fully with the material and ask questions can be tough for any student; this process requires trust. As instructors, we build student trust when we learn their names and connect with them by engaging them in conversation. We are respectful of their efforts to understand and learn. We help our students become better advocates for their own learning when we welcome them to our office hours and guide them to campus resources such as tutoring and counseling. Learning is a social activity. We strive to create a classroom environment that is relaxed, collaborative, friendly and safe in all aspects. Safe to be different, safe to ask questions, safe to try new ideas.

Lesson 5. It takes a team. The studio classroom can accommodate a total of 63 students. For each of the four sections offered in the fall semester (serving a total of approximately 250 students), we employ one professor and three TAs. The success of our studio environment depends heavily on our TAs. With their involvement, our student-to-teacher ratio is twenty to one. In designing a TA training program, we faced the unique challenge of working with chemical engineering graduate students with a minimal background in biology. TA training starts with a boot camp that introduces the TAs to active learning pedagogy, the studio environment, and diversity training (Tanner, 2009a, 2013). During four hours of weekly training, TAs learn biology basics when they prepare and present mini-lectures to fellow TAs. As a group, TAs and instructors discuss how to answer questions in such a way that a student learns to work out the problem independently. We practice the technique of “coach, model, and fade” (Collins, 1991). TA help set up materials for each lab, then complete the explorations and labs the week prior to implementation with students. At week’s end, there is a one-hour debriefing and clean up.

A team provides a support network in which to learn and try new ideas. An effective team can take advantage of the diversity of ideas and backgrounds of team members to promote active learning. Our team includes our university administrators, department head, colleagues, co-instructors, TAs, and the students. As instructors within this team, we have found a supportive environment for reflection and individual growth. We have built upon the successes of our institutional colleagues and learned much from our colleagues at other institutions through workshops and publications. In the summer of 2016, we participated in a month-long activity with faculty members across the university focused on improving the student learning experience at Colorado School of Mines. During the workshop, an Engineered Learning approach (Figure 6) was introduced and was then implemented across multiple departments and disciplines. We have also been fortunate to be part of a professional learning community of instructors throughout the academic year with five other faculty members representing Physics, Math, Petroleum Engineering and Electrical Engineering. Further, the modeling of a team environment by the course instructors promotes inclusivity for our student teams as they tackle the challenges associated with learning in a studio environment.

Lesson 6. Collect evidence and use assessments to inform and improve your teaching. An important first step in pedagogical research and course assessments is obtaining approval for research with human subjects. This process is institution specific; campus resources and procedures should be identified during the early phases of course development. We routinely survey student attitudes about biology and document changes in student study skills, using the
Colorado Learning Attitudes about Science Survey (Semsar et al., 2011) and the Motivated Learning Strategies Questionnaire (Pintrich, 1990, 1993). We also measure learning gains with a fifty-question pre/post biology concept inventory that includes many of the questions from a validated biology concept inventory (Shi et al., 2010). For example, when we assessed student understanding of the learning outcome shown in Figure 4, learning gains for the two questions about this outcome showed, on average, a 82% learning gain (learning gain =((posttest-pretest)/(100-pretest))*100) over 2015-16 academic year. We use course assessments, both formative and summative, to understand student misconceptions; we scrutinize the most common wrong answer in quizzes and exams with the intent of clarifying the delivery of a difficult concept and making our use of class time more effective (Tanner and Allen, 2005). We use the evidence collected throughout the semester (pre and post scores, formative and summative assessments) to identify specific learning goals that are not being addressed fully and strive to correct these issues for the following semester.

While we have begun the process of moving our course toward student-centered learning, we certainly look forward to making further improvements. Students can be reticent to change and suspicious of a different class structure, especially anything that requires more work. In fact, at mid-semester, students often report that they feel they are learning on their own and that the instructors are not teaching (Seidel and Tanner, 2013). We have found, however, that by the end of their semester in Studio Biology, our students seem to have adapted to the new demands of active learning. In fact, most student’s express appreciation for the studio environment and admit to looking forward to attending class as a high point of their week! When asked at the end of the semester “What is Studio Biology?”, student responses included words like “learning, fun, solving, responsible, challenging, proactive, exciting, nurturing, growth and friendship.” In the graphic representation of these responses (Figure 8), the size of the word is directly proportional to the frequency of the response. It is reassuring that the most frequently used words were learning, biology, and hands-on. Fortunately, the cultural climate of an institution changes as students graduate and new students arrive. Word of mouth spreads quickly and students have come to understand that, despite the extra work required, they can expect a positive learning experience in our studio classroom. What was new has become the norm as students engage with biology in a more meaningful and thorough way.
PCAST. (2012). Engage to Excel. President's Council of Advisors on Science and Technology.


Tanner, K.D. (2009b). Talking to learn: why biology students should be talking in classrooms and how to make it happen. CBE Life Sci Educ 8, 89-94.

**Figure Legends**

Figure 1. (A) Original lab space with traditional floor plan and lab benches (B) New studio biology classroom

Figure 2. Workstation design. Philip Greenberg, architect

Figure 3. Studio Classroom is L-shaped, limiting the temptation to lecture. The room is 2300 square feet.

Figure 4. Example Teaching Unit: From Course Learning Goal to Specific Activities: Pre and post instruction assessments address common misconceptions.

Figure 5. Example Teaching Unit: From Course Learning Goal to Specific Activities: Class learning goals and activities help students explore a topic from several perspectives.

Figure 6. Institutional framework to enhance learning and the student experience.

Figure 7. Classroom activities used for different learning modalities.

Figure 8. Student responses to the question "What is studio biology?". Word size is proportional to the frequency of word use.
Each pod has 3 workstations that accommodate a total of 9 students. Central Hub of pod houses sinks and shared group supplies.
Figure 4

**Course Learning Goal:** Describe life's underlying chemical composition, including the basic features of atomic structure and bonding, the importance of water in living systems, and the general structure and function of carbohydrates, phospholipids, proteins, enzymes, and nucleic acids.

**Key Concept:** At the molecular level, biology is based on three-dimensional interactions of complementary surfaces.

**Learning Outcome:** Compare how the properties of water affect the three-dimensional structures and stabilities of macromolecules, macromolecular assemblies, and lipid membranes.

**Common Misconception:** Students do not understand the properties of polar molecules.

**Assessment: Pre and Post Instruction**

1. A phospholipid molecule is diagrammed at the right, and the four diagrams A-D below represent cross sections of spherical structures composed of phospholipids. Which of these structures is most likely to form when a phospholipid is vigorously dispersed in water?

- **A** hydrophilic “water-loving” polar head group
- **B** hydrophobic “water-hating” non-polar tails

2. Consider a short polar charged region and a short non-polar region in a long polypeptide chain. When dissolved in water, the polypeptide will most likely fold to form a protein in which:

- **A** the non-polar region is exposed on its surface and the polar region is interior
- **B** the polar region is exposed on its surface and the non-polar region is interior
- **C** both the non-polar and the polar region are exposed on its surface
- **D** both the non-polar region and the polar region are interior
Course Learning Goal: Describe life’s underlying chemical composition, including the basic features of atomic structures and bonding, the importance of water in living systems, and the general structure and function of carbohydrates, phospholipids, proteins, enzymes, and nucleic acids.

Key Concept: At the molecular level, biology is based on three-dimensional interactions of complementary surfaces.

Class Learning Goals (LG) & Activities

**Inquiry Lab: Milk, Micelles and Membranes**

LG #1: Explain why molecules diffuse and how diffusion of a solute is affected by the solvent.

LG #2: Explain the interaction of soap with the milk fat in terms of hydrophobicity and hydrophilicity.

LG #3: Use the ProScope IR digital camera and LoggerPro software to quantify the dispersion of dye within milk.

**Group Quiz**: Surfactants reduce surface tension of a liquid. Which of the following would result if water was treated with surfactants?

A. Surfactant-treated water droplets will form a thin film instead of beading on a waxed surface.
B. Surfactant-treated water will form smaller droplets when dipping from a sink.
C. Water striders will sink.
D. All of the above will occur.
E. Only A and C will occur.

Exploration: Molecules and Membranes

LG: Read a chemical formula and predict the behavior of a molecule based on the behavior of its functional groups. Name and predict if these molecules would be located in each region (A-D) of the figure.

Exploration: Hydrophobic and Hydrophilic Molecules

LG#1: Describe the properties of hydrophobic and hydrophilic molecules.

LG#2: Distinguish between hydrophobic and superhydrophobic.

Oil and Water Superhydrophobic sand in water

Exploration: Lotus Leaf & Namib Beetle

LG #1: Correlate surface topography with contact angle and degree of hydrophobicity.

LG#2: Suggest several engineering applications for superhydrophobic and/or superhydrophilic materials.
### Figure 7

#### Auditory
- Mini-lectures
- Peer instruction
- Animations with narration

#### Verbal/Linguistic
- Small group discussion
- Group quiz
- TA challenge questions

#### Logical/Mathematical
- Lab calculations
- Analysis of data
- Genetica problems

#### Physical/Kinesthetic
- Molecular models of protein folding
- Amino acid models
- Gene "vapes"
- Genetic code table
- Lab skills (e.g. PCR)

#### Social/Interpersonal
- Group work
- TA challenge questions
- Concept maps

#### Solitary/Intrapersonal
- Misconception and exit tickets
- Learning skills surveys
- Interactive online homework

#### Visual/Spatial
- Concept maps
- Illustration of processes (e.g., photosynthesis)
- Animations with narration
Figure 8
<table>
<thead>
<tr>
<th>Resource</th>
<th>Link to Website</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson’s Mastering Biology</td>
<td><a href="http://www.pearsonmylabandmastering.com/northamerica/masteringbiology/">http://www.pearsonmylabandmastering.com/northamerica/masteringbiology/</a></td>
</tr>
<tr>
<td>HHMI Biointeractive</td>
<td><a href="https://www.hhmi.org/biointeractive">https://www.hhmi.org/biointeractive</a></td>
</tr>
<tr>
<td>Learn Genetics</td>
<td><a href="http://learn.genetics.utah.edu/">http://learn.genetics.utah.edu/</a></td>
</tr>
<tr>
<td>DNA Interactive</td>
<td><a href="http://www.dnai.org/">http://www.dnai.org/</a></td>
</tr>
<tr>
<td>EdX Biology 7.00x. Introduction to Biology - The Secret of Life</td>
<td><a href="https://www.edx.org/course/introduction-biology-secret-life-mitx-7-00x-2">https://www.edx.org/course/introduction-biology-secret-life-mitx-7-00x-2</a></td>
</tr>
<tr>
<td>National Center for Case Study Teaching in Science</td>
<td><a href="http://sciencecases.lib.buffalo.edu/cs/">http://sciencecases.lib.buffalo.edu/cs/</a></td>
</tr>
<tr>
<td>SciTable</td>
<td><a href="http://www.nature.com/scitable">http://www.nature.com/scitable</a></td>
</tr>
<tr>
<td>Biology Concept Lab Manual</td>
<td>M. Decker and R. Wright, 2012</td>
</tr>
<tr>
<td>iBiology</td>
<td><a href="http://www.ibiology.org/">http://www.ibiology.org/</a></td>
</tr>
<tr>
<td>University of Washington Biology Education Research Group</td>
<td><a href="http://uwberg.com/teaching-resources/">http://uwberg.com/teaching-resources/</a></td>
</tr>
<tr>
<td>Q4B Questions for Biology The University of British Columbia</td>
<td><a href="http://q4b.biology.ubc.ca/concept-inventories/">http://q4b.biology.ubc.ca/concept-inventories/</a></td>
</tr>
<tr>
<td>National Academies Summer Institutes on Undergraduate Education</td>
<td><a href="http://www.academiessummerinstitute.org/west/">http://www.academiessummerinstitute.org/west/</a></td>
</tr>
<tr>
<td>Association of American Colleges and Universities Project Kaleidoscope</td>
<td><a href="https://www.aacu.org/pkal">https://www.aacu.org/pkal</a></td>
</tr>
</tbody>
</table>