Active Learning Workshops for Teaching Key Topics in Introductory Cell and Molecular Biology: Structure of DNA/RNA, Structure of Proteins, and Cell Division via Mitosis and Meiosis

Jennifer Hood-DeGrenier*
Biology Department
Worcester State University
Worcester, MA 01602

**Corresponding Author: jhooddegrenier@worcester.edu*

Accepted for publication December 16, 2015

Citation:

Hood-DeGrenier, J. (2015). Active Learning Workshops for Teaching Key Topics in Introductory Cell and Molecular Biology: Structure of DNA/RNA, Structure of Proteins, and Cell Division via Mitosis and Meiosis. *Genetics Society of America Peer-Reviewed Education Portal (GSA PREP)*: 2015.004; [doi: 10.1534/gsaprep.2015.004]

Synopsis:

This resource consists of workshop materials that facilitate an active learning approach to teaching three core topics typically covered in introductory cell and molecular biology courses: DNA/RNA structure, protein structure, and cell division via both mitosis and meiosis. The format of the materials was inspired by the Process Oriented Guided Inquiry Learning (POGIL) technique first developed by chemistry educators (Moog et al., 2009; https://pogil.org) and could be used for instruction using the POGIL method; however, I have used them for group-based workshops without implementing all the structural features of POGIL. The workshops require students to answer a series of questions using the content provided in labeled figures and a small amount of additional information contained in the questions. The questions guide the students through the various learning objectives in order of increasing complexity, allowing them to "discover" the key concepts for themselves rather than passively receiving the content in lecture form. Working in groups, students are able to practice identifying what they don't understand and explaining concepts that they do understand, putting these into words in the form of questions or explanations to their peers. In this manner, students develop a more thorough and hopefully a more lasting understanding of crucial, foundational topics and also practice collaborative problem solving.

Introduction:

The necessity of moving away from traditional lecture-based courses toward student-centered, active-learning approaches was highlighted in the 2011 report, *Vision and Change in Undergraduate Biology Education: A Call to Action* (AAAS, 2011) and has been the subject of many other publications. Many instructors are still uncertain as to how to implement this type of change in their classrooms, however, particularly in introductory courses that are expected to provide students with foundational knowledge of a very broad range of topics as preparation for the next level of coursework. The workshop exercises contained in this resource provide instructors with ready-to-teach group-based active learning modules to replace lectures on three key topics typically covered in introductory cellular and molecular biology courses: DNA/RNA structure, protein structure, and cell division via both mitosis and meiosis. They can easily be implemented within the context of a lecture-based course to increase the active learning quotient without a complete course overhaul. Thus, they can allow instructors to "test the waters" of lecture-free teaching without a large investment in curriculum development.

Approach/Method: (Instructor Guidelines)

I use the workshop modules presented here in the context of an introductory cell and molecular biology course that also includes a significant amount of lecturing as well other, shorter, group problem solving activities. In the overall structure of the course, I use the Protein Structure and DNA/RNA Structure workshops near the beginning—not back-to-back, but within a few classes of each other; the Mitosis/Meiosis Workshop comes later in the semester and is followed by a shorter activity that addresses the events of the various stages of mitosis. (The latter is not included in this resource, but I would be happy to share the activity upon request.)

To implement the workshops, I divide the class into groups of 3-4 students. I have sometimes allowed students to form their own groups, but I find the workshops are more productive if I assign groups with attention to diversity of previous knowledge, overall academic performance, tendency to speak up in class, English language skills, etc. In my experience, 3-4 students per group is the optimum number to promote robust discussion in which all students feel comfortable participating. I give each student his or her own workshop handout but suggest that each group designate one student as a reader to keep the group together as they work through the questions. Because color is important in many of the figures, I provide each group with one set of color figures and also project various figures on the screen as the students work through the problems (but the student handouts are black-and-white to cut down on cost).

I ask students to read relevant sections of their textbook to prepare for the workshops, but beyond the reading (which they may or may not actually do, of course), they have no other previous exposure to the workshop material in my course. Prior to the protein and DNA/RNA structure workshops, the students have been introduced to chemical bonds (covalent, ionic, and hydrogen bonds as well as van der Waals and hydrophobic interactions) and a few key functional groups in organic molecules as well as the general concept of macromolecular polymers and their synthesis via dehydration reactions; this is the only background required for these workshops. For the mitosis/meiosis workshop, the students need to know what chromosomes are and the fact that DNA is the hereditary material. In the context of my course, students would have already been introduced to the cytoskeleton and microtubules, and would therefore have the necessary background to understand the composition of the spindle, but the questions related to the spindle could be modified to remove the details about the cytoskeleton if desired.

During the workshop, groups move through the questions at their own pace. I circulate in the classroom listening in on the groups' conversations, correcting any misconceptions that seem to be persisting and providing clarification to help students arrive at the answers themselves. At several points during the workshop class period I ask students to pause their discussions to answer a few "clicker-style" questions so that I can gauge the degree to which students are meeting the learning objectives. For example, at the start of the protein structure workshop, I ask students to develop their own "rules" for classifying the chemical character of the different amino acids (nonpolar, polar, acidic or basic); after all groups have finished this part of the workshop, I show the class a series of amino acids and poll them as to the chemical group to which each belongs. I have included suggested clicker questions at the end of each workshop as a supplement for instructors. Some questions also refer to web animations or images that instructors can display during the workshops. By actively monitoring the group discussions and bringing the class together at intervals to answer clicker questions or view animations, I find that most students stay on-task and put in the effort needed to learn the material through this guided, non-lecture approach.

After the students have completed the workshop handouts in class, I make answer keys available to them electronically. I give students a small number of points toward their grade for completing the handouts, but I do not grade them for correctness; instead I rely on the group consensus and on individual students taking responsibility to review the answer keys to make sure they understand the material correctly.

Justification:

The workshop materials provided in this resource teach fundamental knowledge that students must master to be successful in higher-level biology courses. I have not conducted a formal assessment on the efficacy of the workshops; however, based on test performance before and after I began using the workshops in my introductory course, my overall impression is that the active learning style of the workshops is more successful than a traditional lecture approach at teaching this material. The workshops are not a “magic bullet”. Students must be willing to put in the effort to interpret the information provided in the workshop figures and to apply it to the questions asked. They must also take responsibility to check their understanding against the answer key. However, on the whole, I find that the workshop approach enables a larger number of students to develop a more detailed understanding of the topics covered than when I have presented the same material in lecture form. They also gain experience mining information presented in figure form and paying attention to details in the figures, which are important skills for success in science. Last but not least, students benefit from collaborating with their peers during the workshops. Scientific research depends on teamwork to a degree that may not be fully appreciated by students; requiring teamwork in the “lecture” part of a course as well as in the laboratory helps students experience the collaborative nature of science and develop skills for functioning effectively as part of a team.

References

American Association for the Advancement of Science, 2011. Vision and Change in Undergraduate Biology Education: A Call to Action. Washington, DC.

Moog, R. S., Creegan, F. J., Hanson, D. M., Spencer, J. N., Straumanis, A., Bunce, D. M., and Wolfskill, T., 2009. POGIL: Process-Oriented Guided-Inquiry Learning, pp. 90-107 in Chemists' Guide to Effective Teaching: Volume II, edited by N. J. Pienta, M. M. Cooper and T. J. Greenbowe. Prentice Hall, Upper Saddle River, NJ.