An evolution in student-centered teaching

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Goodman BE. An evolution in student-centered teaching. Adv Physiol Educ 40: 278–282, 2016; doi:10.1152/advan.00056.2016.—The American Physiological Society (APS) Teaching Section annually honors an educator through its Claude Bernard Distinguished Lecture at the Experimental Biology meeting. Since I knew about my selection for almost a year, I had a long time to think about what I wanted to say and how I wanted to say it. The theme of my presentation was “nothing in education makes sense except in the light of student learning.” My presentation began with a video of my “And, But, Therefore” description of my educational scholarship (see Randy Olson Great Challenges Day at TEDMED 2013, Ref. 10). “Physiology is the basic foundation of all the health professions AND physiology can be hard for students to figure out BUT many physiology courses expect students to memorize a large number of facts; THEREFORE, my scholarship is to help students learn physiology better for the long-term with various types of student-centered learning opportunities.” To stress the goal of student-centered learning, my brief video was followed by a 2-min video of one of my students describing her experiences with student-centered learning in one of my two-semester Advanced Human Physiology classes. Since I have been convinced that Randy Olson is an expert on science communication (11), the rest of my presentation was the story about how I have evolved from a sage-on-the-stage lecturer into a student-centered learning facilitator. I have chosen Olson’s “And, But, Therefore” approach to narrative for this written version of key aspects of the presentation.

I began my graduate career in physiology in the PhD program of the Physiology Department of the School of Medicine of the University of Minnesota in the fall of 1975. At the time, each PhD graduate student was required to serve as a teaching assistant for three of the many health science courses taught by the department annually (even if they were being supported by a research grant). But I wanted to expand my teaching experience for my future career as an academic and biomedical researcher into lecture-based teaching; therefore, as a senior graduate student, I volunteered to teach a night class on human physiology to graduate nursing students. The night class was the same material as my PhD adviser’s course, whereas the undergraduate students. The medical student course offered only a few laboratories during the course, whereas the undergraduate student course offered approximately weekly laboratories during the semester.

Education Training Through the American Physiological Society

As chair of the medical school’s Student Research Committee, supervision of the Minority High School Student Research Apprentice Program fell under my responsibilities beginning in 1989. I had already been a parent volunteer in my daughter’s second-grade class in 1987, so I was excited to become involved in K–12 activities sponsored by the American Physiological Society (APS) soon after they were initiated. I applied to APS to host the local high school chemistry teacher in my research laboratory during the first year of the program in summer 1990. Subsequently, I applied for several APS education grant opportunities and some training grants for minority students, allowing me to develop a number of education outreach and training programs. Beginning in 1998, I was invited to be one of the physiologists-in-residence at week-long APS retreats for summer research teachers that trained them on pedagogical techniques for inquiry-based teaching of science to their students. I served as a physiologist-in-residence four different summers and organized an APS Local Outreach Team in South Dakota to train teachers in the new APS Learning Cycle Units (two of which I wrote with seventh-grade science teacher colleagues) (5, 9). These APS experiences were my first experiences learning about evidence-based educational
practices and new pedagogies (before this I did not even know what pedagogy meant!). I learned a lot about how students learn from the K–12 teacher colleagues with whom I worked! As a liaison from the APS to the Education Section of the American Association for the Advancement of Science for 6 yr, I also learned about someone who was a scientist-in-residence for their local school district and volunteered to create such a position for me with school superintendent approval when I returned from the meeting. I also became involved in a number of other K–12 science outreach activities as a medical school faculty member and was able to write a paper on these partnerships for *Advances in Physiology Education* in 2002 (2).

**Team-Taught Teaching for Medical Students**

My major teaching assignment for medical students upon arriving at USD was a team-taught human physiology course (with one faculty member at a time) that was lecture based (12 h of lecture/wk) with a few laboratories sprinkled throughout the course. As an undergraduate chemistry major at Duke University, the standard approach to active learning had been coupling lectures with weekly laboratories (and recitation sections) facilitated by graduate teaching assistants. The USD School of Medicine version of this was periodic laboratories facilitated by the faculty members who were teaching the content in lectures. Thus, when I taught general physiology (homeostasis and membrane transport), I offered a red blood cell hemolysis laboratory for learning/reviewing transport mechanisms across cell membranes. Other colleagues offered standalone pulmonary function and cardiovascular function laboratories with a total of three additional laboratories scheduled over the 5.5-mo course. To encourage more integrative learning of physiology, in 1998, two cardiovascular colleagues and I (I was teaching respiratory physiology too) decided to change the laboratory experience to a combined cardiopulmonary laboratory with the station method was half of the medical student class of 50 students at a time. Thus, I (I was teaching respiratory physiology too) decided to change the laboratory experience to a combined cardiopulmonary laboratory with six different stations that was offered to half of the medical student class of 50 students at a time. Thus, the cardiopulmonary laboratory with the station method was the first attempt to integrate content from two important systems for our medical students. This led to a publication describing how the laboratory was designed and implemented with the six stations for investigating various aspects of cardiopulmonary physiology (8).

**Question Break:**

- How many of you still have laboratories in your professional student courses?
- How many of you use simulations or demonstrations instead of student-directed laboratories?

**Teaching a Large Biology Major Class**

From 2001 to 2009, I was one of two faculty members to teach Principles of Organismal Physiology (Biology 164, a required course for biology majors that was three-fourths my animal physiology portion and one-fourth a colleague’s plant physiology portion). The course was offered with three 50-min lectures in a large lecture hall (150–250 students) and one content-coordinated 3-h laboratory each week (24 students) facilitated by a biology graduate student teaching assistant. Students were reluctant to participate in the large lecture classroom and were less likely to be engaged with me and my teaching during the lecture period. Therefore, I added a number of think-pair-share activities and minute papers during the lecture time (15). On *day 1* of the course, I asked the students to gather in small groups and write on an index card a few questions that they had about physiology and sign the names of the students in the group. I assumed that the students would be likely to sit close to each other throughout the course. Subsequently, after each of the think-pair-share activities, I called on the students by name by randomly drawing a card (“would one of these three or four students please answer the question based on their group’s discussion?”). I overheard conversations among the students that “she calls on us in class!” Periodically, I also distributed different colored index cards for the students to write answers on at the very end of class to a sample question, such as “what was made clearer in class today or what do you still not understand?” Before the use of clickers in the class, this method was used to randomly check attendance while also soliciting formative assessment from students about concepts that needed to be further clarified. Once the institution committed to the use of clickers in the large lecture halls, I added them to the lecture period with a number of individual assessment questions, polls, and attendance checks. A sample think-pair-share activity used in this physiology class was as follows: “Now that you have an idea about how negative feedback loops work, think about how an electric blanket with dual controls works and what would happen to the newlyweds if the connections were switched. How is this like a physiological reflex loop? What is wrong?” I have routinely used this example when teaching homeostasis and also used it when I was teaching students at Africa University in Zimbabwe in 2005. Even though thermostatically controlled environmental temperatures are uncommon in Zimbabwe, the students quickly answered this think-pair-share activity by saying that the result would be DIVORCE!

To evaluate the impact of using active learning in this large lecture class, one semester we randomly selected one of the nine laboratory sections to accompany the class and provided the students in that small section of 24 students with separate lectures and both a graduate teaching assistant and the faculty lecturer during their laboratory sessions. In both the large lecture and small lecture classes, various active learning activities were incorporated into the lecture time. Students were given a pretest and posttest in physiology, and student learning and student satisfaction were compared between the large and small classes. While there was no difference in student learning, students in the small class thought that being in the small class was an advantage and students in the large class thought that being in a small class could be an advantage (6). Thus, biology departments everywhere should be reassured that student learning is not affected by large lecture classes as long as active learning activities are included during the lecture period.

**Teaching Hands-On Life Sciences for Education Majors**

USD sent a team of science educators to the Curriculum Reform Institute in Oshkosh, WI, in 2002 to redesign the science classes required for future elementary teachers so that they would all be standards based (according to National Science Education Standards). The standards-based life science course (Biology 103 Special Section) was offered for
elementary education majors beginning from 2004 to 2013 by myself and a colleague. Knowing that a high percentage of Elementary Education majors were likely to have deficient backgrounds in science and thus were unlikely to choose to teach much science to their K–8 students, we designed the course with a large variety of hands-on learning modalities, individual and group discussions, and activities (many from the textbook and its web resources) in an extended class period. A number of the activities were chosen because they were either appropriate for teaching undergraduate students life science concepts or they could be used in their future classrooms to teach K–8 students life science standards. Students prepared a science laboratory book portfolio, were evaluated by open-note exams, and worked on several team projects, including preparing lesson plans for their age-appropriate classes. Students in this special class were selected for the class by the survey to evaluate their confidence in teaching science. While attending the regular large-lecture biology class for nonmajors ing lesson plans for their age-appropriate classes. Students in this special class were compared with Education majors enrolled in the regular large-lecture biology class for nonmajors (with weekly teaching assistant-facilitated laboratories) using a survey to evaluate their confidence in teaching science. While students in the special class were selected for the class by the education adviser based on meager science backgrounds, their confidence levels for teaching science to their future students were significantly higher after the hands-on class than those Education majors in the primarily lecture-based class (3).

Question Break:

- How many of you are concerned about the amount of science taught in elementary schools?
- Do you do Physiology Understanding (PhUn; www.phunweek.org) week activities in your local schools? What grade levels?

A Required Interdisciplinary Course for All Majors

Beginning in the fall of 2010, the USD administration revised its signature interdisciplinary education and action (IdEA) program (initially composed of several nonmajor courses and a service-learning requirement to enhance the liberal arts education) to one course for all undergraduate majors that incorporated Board of Regent upper-level writing and global learning requirements. The course (Cross Disciplinary 310 or XDIS 310) was designed by a committee of 20 faculty members and initially used a shared syllabus and theme (happiness) to be taught by 2 faculty members from different disciplines and a PhD student in the English program (for the writing component) in the classroom at all times. A new active learning classroom (9 large U-shaped tables seating 12 students with microphones and computer jacks accessing 1 monitor on each table) was designed for this class of 108 students in 6-person teams based on the University of Minnesota model of active learning classrooms (http://cet.umn.edu/support-services/tutorials/active-learning-classrooms). However, after two semesters of my teaching the course based on the common plan, it was clear that the students did not appreciate a course that strove to teach skills needed for their future careers while choosing to concentrate on resources about how to be happy. Thus, my teaching colleague and I were permitted to redesign the course into a team-based learning experience that incorporated discussions, internet research, writing, team projects, readiness assessment tests for the class material, and the use of clickers to evaluate the skills that they were learning. This new variation of the course was more acceptable to the students; however, the students still highly resented being required to take an upper-level course outside of their major as a junior or senior and thus did not accept the course or its changes. In the meantime, in reaction to the overwhelming student dissatisfaction, the USD administration chose to cancel the course as a requirement (without consulting the faculty members who were teaching in the three to four sections of the course). The experience of teaching this class all four semesters helped me learn how to offer a discussion-based class with >100 students and the usefulness of an active-learning classroom for team-based technology-based activities. A report was published about the design, implementation, and outcomes of the course (4).

Question Break:

- What size class is TOO BIG to do in-class discussions?
- What class seating does not work for in-class discussions?

Advanced Human Physiology: Playing Physiology

When the Department of Biology changed from a four-semester course sequence for their majors back to a two-semester sequence, Biology 164 disappeared and I was able to create an Advanced Human Physiology course (PHGY 420) in 2010, which I continue to teach. Initially, the course was an elective course for students interested in learning physiology for their future careers.

However, in March 2011, a representative ad hoc task force of science faculty members was convened to evaluate the recommendations of the Scientific Foundations for Future Physicians report (7) in light of the established premedical curriculum at USD. In the evaluation of the premed curriculum, several deficiencies were identified in addressing the competencies for incoming medical students that eventually resulted in the design of a new Medical Biology major incorporating recommendations of the Scientific Foundations for Future Physicians and the upcoming changes in the Medical College Admission Test. Since one of the recommendations was a stronger background in physiology for entering medical students, the new major requires an upper level physiology course taught by biology faculty members followed by my advanced human physiology course. Since fall 2012, PHGY 420 is now a required course for new Medical Biology majors (preprofessional students who are planning on advancing into a doctoral health profession for their future careers). The purpose of the class is to help students learn physiology in a different way by doing physiology and learning by teams instead of memorizing physiology facts for examinations (7). The class enrollment has varied from 2 students to an upcoming 48 students offered in a teaching laboratory classroom with an extended class period (2–5 PM on Mondays and Fridays). The course is taught in 3 system blocks (renal, respiratory, and cardiovascular) using a team-based approach with human physiology laboratories and case studies (AD Instruments Powerlabs with Lt, http://www.adinstruments.com/lt#waiting), individual and team readiness assessment quizzes to review physiological concepts from chapters in Silverthorn’s Human Physiology: an Integrated Approach (13), a variety of team projects, and an open-resource take-home essay examination for each block. Teams reflect on the laboratory sessions while doing them on a laboratory summary form, which assists them...
in a class discussion of the objectives of the laboratory in a subsequent class.

Based on the course prerequisites, students are expected to review physiology on their own and rarely are lectures given (an exception is a pulmonary function lecture that was initially designed for medical students). During each system block, teams are required to design and present a project to their peers or to the lay public. Examples of projects include various kinesthetic demonstrations, designing a case study, or preparing educational resources (hazards of secondhand tobacco smoke, e-cigarettes, or marijuana for college students; informational brochures for parents of children with asthma or why kidney damage is a common symptom of diabetes mellitus for patients, etc.). In addition, teams design various components of a teaching module on kidney anatomy and physiology for a 90-min high school block class (including an educational module, case studies, and a game) and present their projects at local high schools. Based on student feedback, one of the best learning opportunities in the class are the individual open-resource take-home examinations with essay-type questions that often have both physiological and pathophysiological relevance.

Now that the cohort of medical biology majors needing to take the course has risen to 48 students, variations on some of the activities will be needed to keep the students in 12 different teams engaged with the activities. For example, instead of having teams do two different experiments with AD Instruments Powerlabs with Lt and the teams teaching the class as a whole what they learned, teams are now paired into small groups of two teams to teach concepts learned to each other. Also, instead of all of the teams going to teach the two classes at the local high school, teams present their modules to their classmates, who vote on which teams have the best teaching presentations, case studies, and games, and only four teams are then chosen to present in the high school classes. In addition to provide more comprehensive feedback on class activities throughout the course, various peer review rubrics have been added and shared with students.

**Medical Physiology for Occupational Therapy Doctoral Students**

Recently, I was asked to design and teach a new physiology course for students in the Occupational Therapy doctoral program. Due to the goal of minimizing required credits, Occupational Therapy faculty members chose to offer a course that addressed four systems [excitable cells (before their neuroscience course), endocrine, respiratory, and cardiovascular physiology]. Occupational Therapy students generally have only a 200-level anatomy and physiology course 4–6 yr earlier as a prerequisite for their doctoral program, and their National Occupational Therapy Certification Exam does not generally expect students to recall specific physiology facts; therefore, I chose to modify my Advanced Human Physiology course design to address their learning needs. Thus, while the new course design still includes team-based projects and activities, human physiology experiments and case studies (AD Instruments), individual and team readiness assessment quizzes based on chapter reading in Silverthorn’s textbook, and open-resource take-home exams, some adjustments were made to nurture student learning/reviewing of physiological concepts. These changes included: one lecture/review of the material including an instructor designed handout with PowerPoint slides at the beginning of each block, a formal points-back option on the individual readiness assessment quizzes (earn half the points back for an explanation about why their answer was wrong and the correct answer was right; a great learning opportunity!), a 50-point multiple-choice and short-essay in-class exam that was taken with a partner, and only a 50-point individual take-home exam with essay questions with physiological and pathophysiological relevance for each system block. Throughout the course, various additional assessments were used to see how the course was going, including background knowledge probes for each block (1), small-group instructional feedback surveys after the first block (14), and a course evaluation at the end investigating what pedagogies helped students learn physiological concepts. The aspects of the course that received the highest average favorable student responses for helping them more deeply understand the material were instructor slides and handout (4.14 of 5.0), points back on readiness assessment quizzes (4.33), take-home tests (4.56), in-class tests (4.25) with a partner (4.42), and working in teams (4.44). Two changes that will be made in the course for the next offering will be to provide more detailed learning objectives to students for both human physiology experiments and the chapter reading/reviewing. The design of this course will be written up for a future submission to *Advances in Physiology Education*.

**Conclusions**

Believing that “nothing in education makes sense except in the light of student learning,” I now deemphasize lectures in my teaching and add a variety of student-centered learning modalities to all of my classes. My endeavors in incorporating student-centered learning in most of my classes convinced me that various categories of student-centered learning can be used in physiology courses to help students learn. Aspects of active or student-centered learning can be incorporated into both large and small enrollment classes even if the classroom design does not allow flexibility for grouping students. Various course and curricula design manuscripts are important and valued publishable educational research. The APS Teaching Section and APS Education Office support many educational activities throughout the year and provide a number of opportunities for improving teaching including:

- Searching the Life Science Teaching Resource Community (www.lifescitrc.org)
- Visiting teaching posters/sessions at Experimental Biology meetings
- Participating in Phun Week activities in local schools (www.PhUnWeek.org)
- Participating in biennial Institutes on Teaching and Learning (www.the-aps.org/itl)
- Joining the Physiology Education Community of Practice and reading the blog posts (http://blog.lifescitrc.org/pecop)

**DISCLOSURES**

No conflicts of interest, financial or otherwise, are declared by the author(s).

**AUTHOR CONTRIBUTIONS**

B.E.G. conception and design of research; B.E.G. drafted manuscript; B.E.G. edited and revised manuscript; B.E.G. approved final version of manuscript.
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