Transforming undergraduate biology education: Concepts, scientific practices, and collaborative instructional teams

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Rationale: Despite many calls for reforming undergraduate science teaching to be more learner-centered, implementation is not widespread. Many introductory biology courses are still taught based on a model of students as passive receptors of lists of facts and topics. In addition, there are real and perceived constraining factors, such as large-enrollment courses taught in auditoriums with fixed seating. Such a learning model may work for students who are well-prepared and self-motivated, but it may leave behind students who could otherwise succeed in the biological sciences, if they were taught more closely to how biologists practice. Thus, students would explore unanswered questions founded upon meaningful concepts, using scientific practices such as evaluating claims and evidence, building and improving scientific models, working with data, and collaborating and communicating with other scientists and non-scientists alike.

Objectives: We aimed to create a sustainable, portable model that collaborative instructional teams can adopt to systematically transform large-enrollment, introductory biology courses. In our system, transformed includes three criteria for describing our courses. Our transformed courses are 1) student-centered – that is, informed by, and responsive to, student learning; 2) built upon biological concepts as described in AAAS’ Vision and Change; and 3) grounded in students learning biological concepts using scientific practices.

Methods: Beginning in 2008, instructional-team members used design-based research methods to develop the model. Founded in principles of Backward Design (Wiggins & McTighe 2005), team members first designed courses that accounted for student learning and potential obstacles to learning. Team members engaged in discussion of course objectives—a discussion that continues to the present day. Team members then used course objectives to drive the design of assessments that provided evidence of student learning. In turn, assessments drove daily course activities. Whether teaching courses focused on cells & molecules or organisms & populations, we based course objectives and units in the same five broad biological concepts: structure and function, transformations of energy and matter, information storage and transfer, evolution, and systems thinking. Rather than being constrained to covering a list of topics, team members are free to select cases, problems, and readings that fulfill these rich objectives. Our courses also focus on core scientific practices of evaluating and building arguments, building and improving scientific models, working with data, and communicating and collaborating. We teach these scientific practices, which support students’ conceptual learning, as deliberately as we teach biological concepts. Our assessments tell us more about student thinking than is possible with traditional multiple-choice (MC) exams, so we are able to rapidly adjust our instructional approaches when necessary. Although our exams take longer to score, we have developed rubrics that allow relatively rapid scoring and that provide feedback to students about the most common errors and how to correct them.

Results: Our students succeed in our courses. Although our assessments scale higher on Bloom’s taxonomy than most MC exams, student grades in our courses are similar to other course sections, and our courses have slightly lower D/F/W rates. Our collaborative instructional team includes both long-term and shorter-term members, and we emphasize mentoring postdoctoral researchers and new faculty. We meet regularly to discuss student learning, potential cases that satisfy one or more deep concepts and scientific practices, and pedagogical questions around how to teach scientific practices.

Implications for Teaching and Learning: We use the evidence we gather in our courses to drive the conversations around student learning in our collaborative instructional team. Our model for course transformation is portable, because it is based on biological concepts that any instructor can use to frame their introductory-biology course. Finally, we have demonstrated that teaching scientific practices in large-enrollment courses is possible and practical, even given the constraints of enrollment and environment at many colleges and universities.