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Feature
Approaches to Biology Teaching and Learning

Moving Theory into Practice: A Reflection on Teaching a Large, Introductory Biology Course for Majors

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PREFACE

While this feature in *CBE—Life Sciences Education* most often translates some aspect of the research literature—from cognitive science, psychology, science education, and other fields—into practical strategies for biology instructors, this installment is purposefully different in kind. Below, I offer a more personal reflection on teaching, motivated by several considerations. First, many of these features have focused on a single pedagogical approach or issue. However, the disaggregation of the many aspects of teaching and learning can belie the complexity of the task of making things happen in a classroom. Practical teaching strategies inspired by research findings may appear only tangentially related to one another, and many strategies are dependent on intangibles related to individual characteristics of an instructor and an institution. In addition, while evaluating research evidence is key in developing effective approaches to teaching, I have found that many colleagues have been inspired to try something new in their teaching from hearing stories of what could be, of the possibilities, regardless of the research behind the stories. Here I am aiming to use my own recent first-time experience of teaching a large introductory biology course for majors to weave together several practical approaches that are grounded in the research literature.

Since the reflection that follows is a personal story, I will emphasize my teaching experiences without unpacking the direct connections to research literatures. That said, all of the teaching strategies I utilized are strongly influenced by and grounded in numerous papers, books, and research studies. Much of the relevant research literature has been previously presented in installments of this feature (e.g., Tanner and Allen, 2002, 2004, 2007; Tanner *et al*., 2003; Allen and Tanner, 2005; Chamany *et al.*, 2008). More specifically, I have learned immensely from those science educators who pioneered active learning and similar teaching techniques (e.g., Felder and Brent, 1996; Silberman, 1996; Wiggins and McTighe, 1998; Bransford *et al.*, 1999; Shipman and Duch, 2001; Fink, 2003), in particular those who have done so in the biological sciences (e.g., Ebert-May *et al.*, 1997; Eisen, 1998; Donham *et al*., 2001; Handelsman *et al*., 2004; Wood and Knight, 2004; Smith *et al*., 2009). The research literatures on situated learning, cognitive apprenticeship, and effective tutoring have played a key role in my perspective on the role of the instructor (Flavell, 1979; Posner *et al*., 1982; Collins *et al*., 1987; Brown *et al.*, 1989; Chi *et al*., 1994; Bandura, 1997; Bransford *et al*., 1999; Shimamura, 2000). And my approach to cultivating instructor–student relationships has been profoundly altered by research on issues of equity, diversity, and identity in the sciences (Tobias, 1990; Rosenthal, 1992; Ladson-Billings, 1995; Steele and Aronson, 1995; Seymour and Hewitt, 1997; Steele, 1999; Brown, 2004; Chamany, 2006; Cohen *et al.*, 2006; Johnson, 2007). These references will not be discussed in this article, but should provide the interested reader with starting points for considering the research that influenced my teaching and this reflection on my experiences.

PROLOGUE

I recently taught the largest biology course, by far, that I have ever taught—an introductory biology course for majors that enrolled ~300 students—at my urban, public, 4-yr university. No doubt many readers have faced similar challenges. As a neurobiologist who has enjoyed more formal training in pedagogical methods than most scientists, I was eager to put to work the many innovative teaching tools I have learned over the years and to apply them in this particular context. As I have considered reflections from my students and reflected on the experience myself, I have been struck by several insights that I would like to share.

I had many worries and concerns in preparing to teach this course for the first time. Would students revolt when

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I asked them to talk to the people next to them? Would the teaching strategies that so successfully engaged my nonmajor students be soundly rejected by majors in the same department? Would I, as a colleague jokingly suggested, really be eaten alive by the experience? Make no mistake, years of experience and training did not prevent my confidence from temporarily waning, given reports about student resistance to innovative pedagogical approaches (e.g., Anderson, 2002, 2007; Silverthorn, 2006).

To presage the conclusion of this story, I did indeed teach the course. I not only survived, I think I thrived. And, no, I did not come anywhere close to being eaten alive! As a means of processing the experience metacognitively, I wrote a final reflection, something I require my students to do in all my courses. This final reflection is usually 1200–1500 words in length and is in response to the following prompt: "What have you learned in this class that will continue to influence you for years to come? How have you learned these things?" This final reflection inevitably gives me insights into what my students have valued in the course, often things that I did not realize were critical for them.

So, what did I learn in teaching an ~300-student introductory biology course for majors for the first time? I had five realizations that I believe will continue to influence me for years to come.

Realization #1: Even in a classroom of ~300, students can feel a personal connection with their instructor, and I can learn their names (mostly).
Realization #2: A ~300-student lecture classroom can be a welcoming and engaging place to be at 8:00 am.
Realization #3: It is important to be on the same team as my students.
Realization #4: Students value learning how to think like a biologist.
Realization #5: I can minimize student resistance by being explicit about the reasons behind my teaching choices.

While I learned a great deal more from this teaching experience than I can record here, I am sharing those insights I think are most widely applicable to all biology instruction in a variety of settings. In addition, since much of what I personally learned came from reading my ~300 students' own final reflections, I am occasionally including their voices here as a complement to my own. The quotes from students presented below were not rare examples, nor are they intended as formal, systematically analyzed research evidence of any sort. The student voices offered are shared because they were a primary source of insight in my own metacognitive reflections on my experiences teaching this course.

MY FINAL COURSE REFLECTION

Realization #1: Even in a Classroom of ~300, Students Can Feel a Personal Connection with Their Instructor and I Can Learn Their Names (Mostly)

I have always considered knowing students personally to be a key part of my teaching. With ~300 students, I was told that was simply going to be impossible. However, just a few months earlier, I had asked a colleague what college science course was her favorite. Without hesitation she had replied, "Oh, that's easy, General Chemistry with Dr. Laird." Why? "Oh, because he really wanted each one of us to learn and tried to learn all 600 of our names in the process. He did not learn them all, but what mattered to me was that he tried, that he cared enough to try."

Learning a student's name, or even just attempting to learn it, appears to go a long way in building a functional teaching–learning relationship between an instructor and students. While simple in concept, it appears to make students feel a personal connection, even in the presence of, in my case, ~300 students. From my students' final reflections came comments like those below:

> "When I signed up for the class I was nervous signing up for such a large lecture, but now that the class is coming to end I must confess that the class was never any less personal than a class of 30 students and not once did I feel lost in the mass of students."

> "This has been one of the most personal classes I have ever taken at the college level. Even though there were more than 270 students in the class, the professors made each individual feel like they were somebody and strived to make sure every student was doing well in the class."

As another example, I received many emails over the course of the semester that suggested students felt I was aware of their individual behavior during class. . .

> "Hi Kimberly, I wasn't sure if you noticed I kind of dozed off for a little while in class today. I want to apologize and let you know that it's not you. It's me because I didn't sleep due to homework. I feel bad because you try to be positive and enthusiastic. I will try to stay awake next time. Sorry, Elena"

While it may seem daunting to learn the names of students in such a large class, there were a few simple strategies, recorded below, that aided me greatly.

Use Name Cards in Lecture. In most of my classes of fewer than 50 students, I have used a folded 8.5 × 11 piece of cardstock marked with the first name of each of my students to make an individual name card for each student. These name cards have been indispensable tools in my courses for learning names, constructing groups, and encouraging students to get to know one another. On the first day of this large course, every student received a bright green name card and was asked to write his or her name in large letters on the front and the back. I expressed the desire not only to learn their names, and explained the importance of learning together as a community, even a big one. It was not just important for me to know their names; it was important for their colleagues (other students) as well. See Figure 1.

Further, these name cards are also assessment and memory devices. Prior to folding them, I print a grid on the back that has an entry space for each class meeting during the semester. I often pre-enter into this grid important dates, like exams and holidays. The rest of the spaces are left blank. In classes of smaller size, where I have the luxury of more time, I ask a question at the end of each class that students can respond to in the space for that day. On the first day of this large course, I explained the dual purpose of these name cards. I expressed that as a neurobiologist I recognized the name cards were an excellent tool for them as students to record

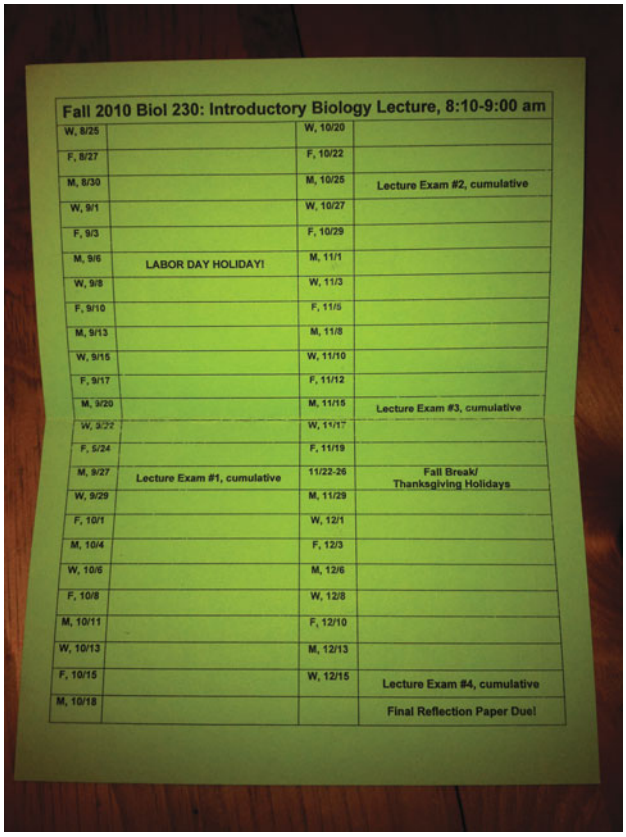

Figure 1. Inside of lecture name card.

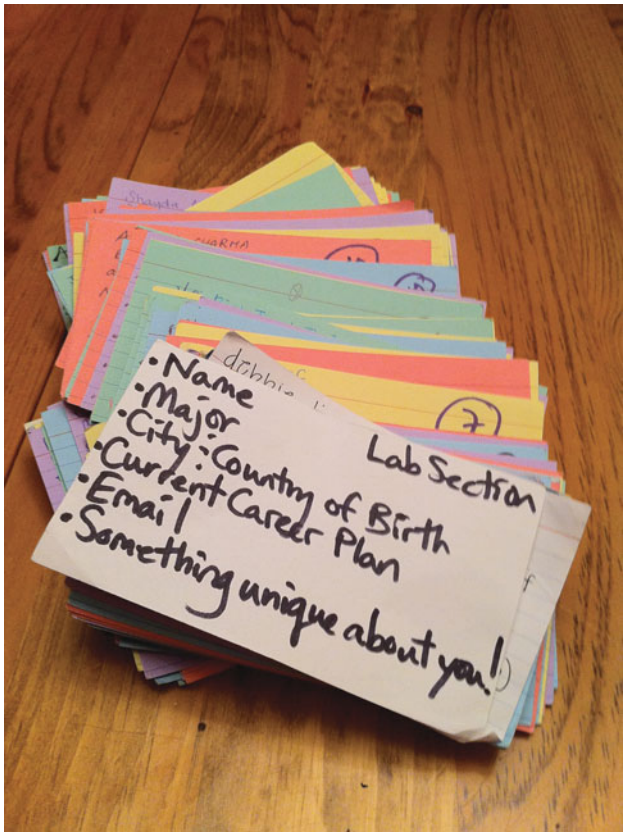

Figure 2. Personal index cards.

something—be it an aha moment, a frustrating confusion, or any other anecdote—that would help them to remember the class session experience for that day and distinguish it from the other 44 class sessions we would be spending together. While recording these entries was not required, it was strongly encouraged. At many points during the course, students asked whether I wanted to check their name cards. They would share particularly funny or meaningful entries with me. And at the final exam, a surprising number brought in their card to show me how useful it had been for them in tracking their experiences through the semester.

Build a Personal Information Index Card Directory on the First Day of Class. While the name cards were immediately useful in class, even more helpful was the collection of a "Personal Information Index Card" from each student on the first day of class. Students were asked to provide the following:

> Your given name, and the name you want to be called
>
> Your major
>
> Your email
>
> The city, state, and country where you were born
>
> Something unique about you that is not true of anyone else in this room

I referred to this stack of ∼300 index cards regularly while I was teaching, and I still have the cards and refer to them on occasion. It was immensely useful in learning students' names by associating names with majors and unique characteristics. See Figure 2.

Take Their Pictures with Their Name Cards. The most critical thing that I did with the name cards was to take each student's picture—with his or her explicit permission—with the name card in front of the individual in the picture. I did this in the laboratory sections during the first 2 wk of the course. As I took the pictures, I asked what they had written on their index card the first day of class that was unique about them. This was immensely helpful! Oh, you were the one who: was attacked by a monkey, writes jingles, is a professional photographer, died for 4 min, eats only macaroni and cheese, etc. The mechanics of obtaining the photographs was probably even more important than taking them. It meant that within the first 2 wk of class I had had a personal conversation, albeit ∼1–2 min long, with each student in my course. See Figure 3.

Assign a "More about You" Survey as Homework on the First Day of Class. While the name cards and personal information index cards were immediately useful, they were quite limited in the amount and type of information collected about a student. So, the first homework assignment given on the first day of class was an online "More About You" survey that consisted of 30 questions of four types. Many of these questions were closed-end, multiple-choice questions, so that the online survey software provided a synthesized output of the profile of students in the course. These questions were mostly factual: major, class standing, contact information, transfer status, gender identification, languages spoken, and cultural/ethnic

Figure 3. Student (graduate teaching assistant actually) with name card.

identification. Strikingly, I found out from this survey that about one-third of our students in this "majors" course were not biology majors, but rather kinesiology, biochemistry, and other majors. Other questions probed students' current career goals. There were also conceptual questions that probed for common misconceptions in biology and gave me insight into students' baseline ideas on a few core ideas that threaded through the course. Finally, there were questions that asked students what had been most effective in supporting their learning in previous biology courses, what had been least effective, and what else should be known about them as a learner. These last questions became most useful later in the course in working with students during office hours and assisting them in thinking about how to increase their learning and success in the course.

Make Coming to Office Hours a Part of the Course. As I have done for smaller classes, I included in the syllabus the following: extra credit is available for meeting for at least 10 min during an office hour session to discuss your progress and feedback for class (15 points). By the end of the semester, more than one-half of the students in the course had taken advantage of these office hours appointments for extra credit and many were repeat visitors, even though credit was only awarded for the first visit. While I do not have a rigorous comparison, I predict that I would not have had these hundreds of one-on-one conversations with students about their career goals, their school struggles, and, importantly, about biology, if this office-hour incentive had not been structured into the course.

Say "Hello" on Campus and Do Not Be Afraid to Ask Their Names. There were many times when I simply could not remember students' names. The final strategy I offer is honesty. Many times I had to share with a student that I could not remember his or her name. Never did I feel that students were insulted, nor did I feel that they were disappointed in me. Remembering someone's name is a placeholder for knowing them and wanting to interact with them. I got a lot of credit just for trying, much as one may when attempting to speak the language in another country. I see those students around campus constantly. I call many but not all of them by name. And they call me by my name, too.

Realization #2: A 300-Student Lecture Classroom Can Be a Welcoming and Engaging Place to Be at 8:00 am

While the class size could have been bigger, the class time could not have been earlier or shorter—it was scheduled at 8:00 am on Mondays, Wednesdays, and Fridays for 50 min. Despite this, a variety of simple teaching techniques appeared to cultivate a positive atmosphere and build a sense of community, making the classroom a welcoming, comfortable place to be, as reported by the students:

> "I wasn't sure what to expect when I walked into Biology 230 for the first time, so I think it's fitting to start my reflection with that experience and how it affected me throughout the semester. I was extremely surprised at the size of the massive lecture hall with music playing when I first walked in. I quickly grabbed a spot in the middle of the movie style seating and noticed a strange contraption on the stage at the front of the class. A large rectangular box on stilts with a question mark on the front and a funnel protruding from the bottom was placed in the middle of the stage on top of a table. I had no idea what the 'mystery box'could have to do with a biology class, but was intrigued by how it worked and what was going on inside. . ."

> "I've always been a very solitary person, especially in my academic career. This class helped me realize that I don't always have to do things on my own and in many cases it is detrimental to do so."

> "In lecture I also really enjoyed taking time to discuss things with my other classmates. Anytime there was a clicker question and we got to discuss it, I felt that had two purposes. The first was to get us to talk to people we may not have known very well or at all, and we got to throw ideas off each other to come to a conclusion about the question given to us. Another reason it was nice to discuss questions among my peers was because it was an 8 am class, and talking to other people helped wake me up in the morning. . ."

Make the First Day of Class about Science and Not the Syllabus. On the first day of class, I think the most important thing that I did was NOT read the syllabus. The first day of any course, like the beginning of any new experience or relationship, is full of expectation and excitement. In our first 50 min together, we did science together and got to know one another. As described above, collection of the personal information index cards, making their student name cards, and meeting some of the students sitting around them were critical activities. But that was not science. So, on the first day, we did a problem-solving challenge called the Mystery Box, in which water is poured into the top of a box and may or may not come out of the bottom of the box, changed or unchanged, depending on the setup of the box. The students were immediately engaged in making predictions, recording observations, proposing and comparing models, and revising these models based on new observations. While the Mystery Box is a wonderful tool, there are dozens of ways to engage students in the habits of mind of scientists on the first day of class.

Come to Class Early and Make Yourself Available. This is not always possible in the busy lives of instructors, but

simply being in the classroom for some period of time prior to the start of class appeared to be important in making me accessible and unintimidating to students. While the 8:00 am start time of this course was not optimal in many ways, it was a luxury in that our classroom was open and available. I used this time to mingle with the students, not to busy myself with my computer, shuffle papers, or otherwise appear hidden behind the podium. In the beginning of the semester, I needed to be the initiator of conversations, to actively talk with students, approach them, ask them how it was going, and be friendly. Later in the semester, I generally did not need to approach students, because they were approaching me. I did not talk with every student, but used this opportunity to meet and talk with students I did not usually see in office hours or who tended to sit in the back row. I consciously made sure I did not always talk to the same students. We talked about the course, but I also asked them how the semester was going, what they did over the weekend, and things I would talk about with any other professional colleague.

Look Thrilled to Be There. Like most faculty, I was at many points overwhelmed during the semester. In addition, this class was at 8:00 am, Mondays, Wednesdays, and Fridays. Ugh. But when I was in class, I viewed it as my job to look thrilled to be there. And this did seem to have an important effect on my students. If I was not excited to be there, how could I possibly expect them to be? There are a variety of ways to express enthusiasm for being there, and even more ways not to. It takes conscious effort to remember that you as the instructor set the tone for the classroom.

Share about Yourself. At many points in the semester, I strategically and purposefully shared my own experiences with students. On the first day of class, I shared that I was a first-generation college-going student, and that there were no other scientists in my family. For many of the students at my university, this is an important point of connection. After their first exam grades were returned, I reminded them that I was a PhD-level neurobiologist and then promptly shared that I had, in fact, failed my first neurobiology exam as an undergraduate. At multiple points during the semester, I shared that I was a working parent, like many of them. On numerous occasions, I emphasized the vastness of the field of biology and how it was really no longer possible for individual biologists to be expert in all the subfields of the discipline. Numerous students have recounted that these stories somehow "took the edge off" for them. I became one of them instead of an "other" without similar experiences or an empathetic stance, and my success looked like something they could achieve. A danger in this approach is one may appear either unknowledgeable or unprofessional. Another danger is cultural incompetence, and making assumptions that the stories you share are relevant, when in fact they are not, or they inadvertently reinforce stereotypes of science and scientists. So, sharing of yourself can be a teaching tool, but it must be judiciously used, usually for specific purposes at specific junctures during the course.

Commit to Making Time for Students to Talk during Class. There was no class session during my teaching in this course in which students did not have an opportunity to exercise their voice at least once, and usually multiple times, during class. The simple "think-pair-share strategy" is as possible with 1000 as it is with 10. Like any other novel strategy that students may be unaccustomed to, it takes time to entrain such classroom behaviors and interactions. I most often used teaching strategies to get students talking at the beginning of a class period, usually to discuss homework that they had been doing in preparation for class. In addition, a quick 2-min discussion around clicker questions became an expectation, such that not talking about a clicker question would be a surprise and a disappointment to some students. Not all the students in my ~300-person community were thrilled to talk with their neighbors, but in examining students' final reflections, I found these students were a small minority; the majority of students valued a chance to hear the perspectives of their peers and share their own views. Why the lack of resistance? Four things may have made a difference. First, I openly acknowledged that having students talk in class with others would put some students out of their comfort zone, while simultaneously putting other students in their comfort zone. I expressed that my job as an instructor was to have no individual chronically out of his or her comfort zone. Second, I kept the time for talking short, but periodic and recurring. Third, I actively worked with those students I saw not talking with others to get them engaged in a group. After several class sessions, I had to do this much less often, because they knew I was coming their way if I did not see them engaged in talking with peers. Fourth, the things I chose to have them talk about in class appear to have been interesting to them and complex enough that multiple perspectives were possible and intriguing. The choice of what to have students discuss appears to be much more challenging than the mechanics of getting them to talk.

Explicitly Encourage Student Collaboration and Study Groups. On multiple occasions during those 10–15 min before class, I introduced students to others who had something in common, shared interests I had discovered through their online Biologist Journal entries. I encouraged students to find study buddies and form study groups, especially in the context of the laboratory sections. As this cohort of students has gone on to the second semester of this introductory biology series, I have heard from numerous students that it was a relief to walk into that next course knowing so many classmates and having some established study partnerships and groups that would continue to serve them in their biology studies.

Play Music during the Time before Class Starts. I had the luxury of an 8:00 am class with no prior class to prevent my occupation of the classroom. Since I needed to wake up and so did my students, I made it a policy to play music for the 20 min prior to the start of class. In fact, I invited and began to get requests on a regular basis, which was wonderful, as we had music in a variety of languages and styles over the course of the semester. This strategy is certainly not possible for everyone, but if feeling welcome, comfortable, and at ease promotes learning, strategies such as these are not inconsequential.

Realization #3: It Is Important to Be on the Same Team as My Students

One of the most striking things I have experienced as an undergraduate biology educator is the assumption that instructors and students play opposing and sometimes adversarial

roles. While I had experience in cultivating a relationship that put me on the same side as my students in classrooms of fewer than 50 students, I had sincere concerns about whether I could accomplish this with ~300 people sitting down in a room and me generally standing up. Even the body language of the situation put us in roles that I wanted to change. Reflections from students suggested that, even in a large class, we could cultivate a teaching and learning partnership where we were on the same side.

> "The professors in Biology 230 were amazing because they seemed to really care that the students understood the material."

> "The fun I had learning this year in this biology course was really unexpected. . . Before enrolling in the course I heard horror stories about how the class was really difficult and that there was a lot of material to cover for each exam and how it was very difficult to pass the class with a high grade. This is all true but I felt like this year things changed, the teaching was so effective that it literally made things a lot simpler and easier to learn."

> "[This class] made me realize that I haven't been learning but competing in school, which is such a tragedy. All I have been thinking about is grades, and not really what I could get out of it in the end. . .This class has taught me pursue those things, and try not to make everything about grades."

Strategies that appeared to cultivate a partnership between students and instructors were neither specific activities nor anything particularly dramatic, but rather habits of language and interactions that were purposefully collegial.

Treat Students as You Would Your Professional Colleagues. In my own scientific training experiences as an undergraduate, graduate, and postdoctoral student, I have personally valued being treated as a scientific colleague even by those who had far more experience and wisdom. In response, I have generally taken the stance that students are my colleagues, and refer to and treat them as such. The use of the term "colleague" seemed to aid a great deal in forging a partnership between my students and myself. Even simple acts that indicate respect, such as replying to an email in a timely fashion, were much appreciated.

Use Language That Puts You All on the Same Team. The use of "you" is problematic. It has an accusatory tone and is generally unhelpful. Phrasing my professional interactions with students using "I" or "we" instead of "you" language served me very well in a ~300-person classroom. Early on, the phrase "Team Bio 230" emerged as a way to refer to all of us collectively. In addition, when students' performance on an assignment was unexpected, I did not use language of "you all" or "you" or "they," rather it was about "we." While this may seem trivial, our language often belies the true nature of our beliefs. If we really believe that we are partners with our students in learning, our language should support that.

Solicit Students' Feedback Regularly on How the Course Is or Is Not Supporting Their Learning. Through weekly online journal assignments, students were involved in writing regularly about their experiences in the course. While most of these Biologist Journal entries were focused on grappling with conceptual confusions or unpacking case studies, some were used to solicit student feedback on their learning in the course. They were not asked what they "liked" or "enjoyed," but rather what "most supported" or "least supported" their *learning of biology*. The regular invitation for student voice and opinion on the effectiveness of the teaching and learning process is an important way to construct a situation where the instructor and the students are on the same team. Interestingly, the aspect of the course that students consistently said least supported their learning was reading the textbook, which they found disjointed, jargon-laden, and confusing.

Strive to Think Like a Student. I believe it is easy to make assumptions about why students are not successful in our courses, rather than attempting to understand their experience. One of the key habits of mind that guided teaching and learning in this course was to "think like a biologist." At one point, a student approached me and said, "I really like the fact that you seem to think like a student." In structuring our work together, I did take into account when students would be experiencing intensive work due to the laboratory portion of the course and tried to then minimize the demands occurring from the lecture portion of the course, which I controlled. I did assign work over weekends and breaks, but I tried to assign it early enough so that individual students who had family obligations or just wanted a real break could complete the work in advance. In addition, I assigned page ranges in the textbook for reading, as opposed to entire chapters. I often find that there is far more information in a textbook than either I want students to learn or that they are likely to be able to learn. Being thoughtful and judicious about indicating the pages in the text that were really, really important was an appreciated aid to students. Finally, every day in class, I posted an agenda for what we were going to do over the course of the next 50 min and the guiding question that we were trying to understand (e.g., "How can mutations in DNA contribute to the development of cancer?"). This was perhaps in response to my own experiences as an undergraduate student, where I was frequently at a loss to express what had transpired in my class sessions or what the point had been. And, importantly, I was explicit with students about my attempts to "think like a student" in structuring our work together.

Make the Conversation about Learning and Not about Grades. Early in the course I spoke very directly about the purpose of the course being about *learning biology*. I expressed to students that with ~300 students, there would be a lot of accounting, and I always wanted them to alert me to any recording errors in keeping track of the grades they had earned; however, I expected our one-on-one conversations to be focused on issues of learning and issues in biology. Grades were something they earned, not something I assigned. Grades were determined not solely from exams, but also from weekly Biologist Journal entries, homework assignments, in-class clicker participation, in-class index card participation, the laboratory portion of the course, and even their final course reflection. These strategies reduced discussion of grades to only a few students, and with them only rarely.

Care about and Believe in Your Students. This strategy seems like stating the obvious. That said, I have encountered many faculty who express something to the effect of "some students will do fine no matter what, some are hopeless, and there are

the few in the middle that you can try to help." But by knowing my students, I was often able to offer support and options that enabled them to keep going, to make strategic decisions about their education, and to believe in themselves and their potential for academic success, even in the face of personal or academic difficulties. It seems an obvious statement that if we do not believe in students, we risk that they will not believe in themselves. And if they do not believe in themselves, they have little chance of persisting in the face of the challenges inherent in biology learning.

Realization #4: Students Value Learning How to Think Like a Biologist

I have asked colleagues who teach upper-division biology courses what they really want students to leave introductory biology being able to do. The answers are quite divergent, but no colleagues have ever provided me with lists of detailed mechanisms or even conceptual ideas in biology. Most, at the core of their answer, express a desire for students to be able to think critically and skeptically and know how to learn. This goal of teaching students how to learn and think like biologists was central to the course and valued by students.

> "Biology 230 has also taught me to think. Quite a bold statement, I agree. But I simply realized after finishing this course (completely finishing after I submit this essay), that it's not enough to read, memorize, or even comprehend. I think that in order to really grasp a lesson one must ask questions, identify confusions, use evidence, and be skeptical. In order for one to cultivate wonder, one must look at something from every angle and want to learn it and not just think about it in a normal sense of things."

> "Also, another important concept or concepts, I will always remember is U-ABC-IT, which is something that will be always useful in whatever class I take whether its lower or upper division classes. Use Evidence, Ask Questions, Be Skeptical, Cultivate Wonder, Identify Confusions, and Think Like a Biologist are the main concepts one should use always in life and maintain their mind open to new ideas and view things skeptically. I believe that if we use all these concepts, we can become better scientists and analytic persons."

Be Explicit about the Scientific Habits of Mind That You Want Students to Cultivate. On every day of class, from the first day of class, there were six posters with colorful lettering that were hung on music stands on the stage of the classroom. These six posters read as follows: Use Evidence, Ask Questions, Be Skeptical, Cultivate Wonder, Identify Confusions, and Think Like a Biologist. These scientific habits of mind, which constitute part of the learning goals for all of my biology courses, appeared to play an important role in helping students aim for learning, rather than just memorizing information during the course. Of course, there were things to memorize, and many students seemed to do this well. Most, though, appeared at a loss for what else to do. The U-ABC-IT posters (as they came to be known) were used in lectures and made constant appearances in students' writing in their Biologist Journals, aiding all of us in keeping a focus on the habits of mind that we were attempting to cultivate in this introductory biology course. See Figure 4.

Figure 4. U-ABC-IT posters.

Model How You Have Struggled to Understand Biology Yourself. A strategy that worked well with students was to find examples in the material where I could remember the challenge of learning. I explicitly told students that it would not be unusual for them to feel that a concept was clear when I explained it in class or when they read it in a book, but then confusing when they began themselves to write about the idea or apply it to a problem or case study. Even the act of alerting students to this common experience of confusion in learning appeared to be reassuring to them. Whether it was aiding students in thinking across size and scale or envisioning our classroom as the inside of a functioning eukaryotic cell, this kind of "cognitive apprenticeship" or "cognitive coaching" during our lecture time together seemed valuable to students as they themselves were learning to think like biologists.

Engage Students in MetaCognition in and out of Class. Approaches promoting students' metacognitive skills—the ability to think about what one is thinking and evaluate one's own approach to learning—were welcomed and valued by my beginning biologists. These ranged from a 1-min paper on an index card expressing any confusions concerning the biological concept at hand, to a Biologist Journal entry after the first exam, in which they wrote a letter to themselves about what was most and least effective in how they had studied and prepared for that exam. For many, this assignment, which they returned to prior to the second exam, was eye-opening.

Realization #5: I Can Minimize Student Resistance by Being Explicit about the Reasons behind My Teaching Choices

While much has been written about the potential perils of integrating active learning into undergraduate science courses, I have trouble identifying much of any resistance in this case. I would speculate that the primary reason was that I was quite explicit with students about what we were doing in class and why. In fact, the constant stream of small assignments that engaged students in active learning and self-assessment throughout the semester appeared to be welcomed. In their reflective journals, students reported feeling that a number of the teaching choices I had made, many involving teaching strategies initially unfamiliar to them, did effectively support their learning:

> "What I really liked about the lecture class was the homework that was given to us. I felt that the homework really contributed to my studying because we had to utilize all of the concepts we learned in order to do them."

> "At the start of the semester I honestly thought that the journal entries would be such a time consuming, tedious job, but it contributed to my learning a great deal!! Without the journal entries, I don't think that I would have understood the material as well as I have. I love learning more fascinating facts about science, and the journal entries along with the articles we were required to read, provided me with materials to explore science further."

> "When I found a way to connect what I was learning in the classroom to something in my life, it made it easier to remember. When we were learning about cellular respiration and photosynthesis I remember putting my hand up next to my mouth and breathing out. I knew we breathed out carbon dioxide, but actually feeling the water come out too helped me to remember which equation was which. This I will always remember."

> "Concept mapping really helped me understand the digestive system. . . I believe that this technique of concept mapping I will always use in future classes when I don't understand certain things or have a problem relating terms, ideas, or concepts."

From my experiences, the following strategies are concrete ways to engage students in their own learning and be explicit with them about how this will benefit them not just in the current course, but also in their careers and lives.

Give Them More to Do Than Just Read the Textbook. For many students, the lecture (not the laboratory) portion of science courses consists of lectures, assigned textbook readings, and exams. However, the tenets of active learning suggest that we engage students in a variety of small assignments to help them grapple with the material, direct them toward changing their minds about common misconceptions, and provide explicit opportunities to connect biology learning to the real world, their personal lives, and their own opinions. The most highly praised (by students) pedagogical tool that I used in this course was reflective writing, followed closely by case studies and concept mapping. For some students, reflective writing in online Biologist Journals and case studies were beloved, while for others concept mapping was a transformative discovery. While the mode of active learning preferred by students varied, active learning in general was welcomed.

Allude to How Students Can Apply Learning Strategies to Other Courses. Throughout the course, there was an emphasis on the applicability to other courses of the learning tools being used in our course. Early and often, I stated that the purpose of this introductory biology course was to prepare students to learn in upper-division biology courses, where the content would be more detailed and the pedagogical approach likely more traditionally lecture-based. Students were encouraged to take the reins for their own learning in this course, and in others. Students seemed shocked by the statement that college would be over before they knew it, and they would still need to know how to go out and learn on their own.

Connect Learning Experiences in Your Course to Other Courses They Will Take. A common complaint among biology faculty is that students enter upper-division courses without a solid understanding of the basics, for example, how genes encode traits (central dogma). So, when we worked on this conceptual area, I introduced pictures of upper-division faculty and the courses that they teach in which central dogma would play a key role. And I challenged my students to learn the concepts not just for the present course, not just for our exams, but also for upper-division courses, in particular, and for their professional lives, more generally. Motivating learning in this way appeared to raise the stakes and minimize the importance of learning for the short term, for exams, and for grades.

Make Learning in Your Course about Learning for the Real World. Biology is the study of living things. Unfortunately, even with a great deal of change in textbooks and curricular materials over the years, biology courses can still feel abstract to students and unrelated to things they care about. I was explicit about how we would be doing a lot of real world–like work to prepare them for grappling with biology problems postcollege. Case studies were a wonderful strategy that made the relevance of the biology we were learning explicit. Students were challenged to defend or refute a connection between the candy Altoids and mad cow disease early in the course to guide our evaluation of "living" and our exploration of the different classes of biological macromolecules. The case of marathon runner Cynthia Lucero (who died of hyponatremia) and the exploration of the cholera outbreak in Haiti were both striking entry points for students in understanding the importance of osmosis. Finally, the integration of real people from a variety of different backgrounds and their involvement in the discoveries that we had studied were noted by students on the final exam: Henrietta Lacks, Rosalind Franklin, Stanley Prusiner, Maurice Wilkins, Lynn Margulis, Erwin Chargaff, Francis Crick, George Washington Carver, Phineas Gage, Elizabeth Blackburn, Louise Brown, and Henry Molaison.

Highlight the Diversity of Learners and the Role of Being out of One's Comfort Zone. Finally, I have thought a lot about why my students were more accepting of active learning strategies than predicted. I believe communication was critical. I was explicit with my students that aspects of my teaching might be highly effective for some of them while simultaneously being benign or perhaps even frustrating to others. I was explicit with them that they would at times be in their comfort zone and at other times out of their comfort zone. My commitment to them was to provide points of entry for all of them and to make sure that no learner was always out of his or her comfort zone. I compared teaching to having a tool belt: the hammer (lecture) is a great tool, but not for all tasks. Sometimes you would be better served by using a wrench (case study) or a screwdriver (concept map). This explicit discussion of the diversity of learners in the room and the requisite need for a diversity of teaching styles may have been the preventative strategy to blunt the possibility of revolt. Even students who most enjoyed lecture and would have thrived in a lecture–text–exam cycle classroom would reflect in their Biologist Journals that they saw the merit of the different teaching strategies for some of their colleagues.

In Summary

So, what did I learn in teaching a ~300-student class for the first time? In general, I learned that many assertions I had previously heard about the values and behaviors of

students in a large introductory biology class for majors did not resonate with my own experiences. The same pedagogical approaches may work differently in the hands of different instructors, and sometimes intangibles may be at play, aspects of teaching that are stylistic, affective, and centered on the student–instructor relationship. These "intangibles" should make everyone skeptical of teaching discussions that make claims about "what works" in any general sense. Teaching is a social endeavor about personal relationships. What I learned in teaching the largest class that I had ever attempted was that these personal relationships did not just disappear. They are there if you notice them, cultivate them, and honor them; in fact, they are a major asset in accomplishing our teaching goals. Finally, metacognition is not only important for students learning about biology, but also for instructors' learning about biology teaching. While it is neither possible nor desirable for every course we teach to become a full-scale research project, we can cultivate a scholarly, scientific, and metacognitive approach to teaching by purposefully reflecting on our experiences and student evidence collected along the way.

POSTSCRIPT

The reflection above is singularly my own and in no way represents the perspective and opinion of others affiliated with the teaching of this course. I am immensely grateful for the collaborative efforts of my co-instructor Dr. Zheng-Hui He. While I led instruction during the first and last quarters of the course, Zheng-Hui led during the second and third quarters with his own approach and style. We met weekly to collaborate and strategize, attended one another's lecture sessions, and attempted to make connections across our sessions. The graduate teaching assistants and lecturers who were the pedagogical leaders in the laboratory sections graciously used name cards in the laboratories to aid me in learning names, but they were not asked to adjust their teaching styles to match mine in any way. Two part-time graduate assistants—Stephen Ingalls and Issam Jadrane—shared in the participation-based grading of online Biologist Journals, index cards, and concept maps, as well as the rubric-based grading of open-ended exam questions. They attended and audiotaped every lecture session, and graciously assisted when classroom materials setup was more complex. Everyone affiliated with the course functioned as wonderful thought partners through hallway conversations, email chats, and other informal interactions.

The inevitable question will arise about how much time was involved in my approach to this course. I did not track this, but note that the approaches I took that seemed to be most effective did not require extra time, but a different use of time before class, during class, in preparing class sessions, and in structuring office hours. For example, I did not read every Biologist Journal from every student every week. Generally, reading about 10%—about 30 journal entries—of ~300–400 words each would give me a good sense of the range of ideas present among students. I worked on learning the names of students while waiting in line for my lunch or in any other place where I was waiting and could use my phone to access their pictures. I tried to make my appointments with students ~15–20 min each, so that I could see 8–10 students a week during my regularly scheduled office hours. So, while assistance in grading written work may be critical, many of the strategies presented above can serve as small starting steps toward changing the nature of an introductory biology course with as little or as much investment of time as desired by an individual instructor.

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