Learning and Doing: An Interview with Bill Wood

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THE Genetics Society of America's Elizabeth W. Jones Award for Excellence in Education recognizes significant and sustained impact on genetics education. As well as having made major contributions to biochemistry and developmental genetics, the 2016 awardee William B. Wood has been a pioneer in the reform of science teaching. Wood's leadership has been crucial in several national initiatives and programs, including the development of the influential National Academies Summer institutes on Undergraduate Education in Biology. He has also catalyzed change in education through his service as Editor-in-Chief of *CBE-Life Sciences Education*, a peer-reviewed journal published by the American Society for Cell Biology, in editorial partnership with the GSA.

How Did You First Become Interested in Education?

When my kids started school in the 1970s, I got interested in what they were going to experience, and I was impressed by a book called "How Children Fail" by John Holt. His message was that for kids to learn, they need to be doing things, not just listening to a teacher. That was my introduction to active learning. I tried to apply the same ideas to the biochemistry course I was then teaching at Caltech, to make it more interactive and engaging, and this eventually resulted in our unorthodox textbook "Biochemistry, A Problems Approach." But then over the next 30 years as I moved to University of Colorado and began teaching developmental biology and developmental genetics, I focused on the content and didn't really think much about how I was teaching it. I think I generally gave good lectures, and I got good student ratings, but it was pretty traditional teaching. Then, in the late 1990s, Bruce Alberts twisted my arm to serve on a National Research Council (NRC) committee that was evaluating high school advanced placement programs. The committee consisted of high school teachers, university scientists like myself, and educators. The educators used a lot of jargon that was hard to understand but I soon realized that they knew a lot about how people learn, and that there was a substantial literature out there that could be applied to college-level teaching.

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How Has Your Own Teaching Changed Over Your Career?

It changed substantially in the years after my experience on the NRC committee. Up until then my junior colleague Jenny Knight and I cotaught our large developmental biology course as we had been taught, primarily by lecturing. But then in the early 2000s, again at the instigation of Bruce, Jim Gentile and I were appointed cochairs of a small National Academies committee charged with designing a workshop that would introduce college-level instructors to some of the findings of the new research into how people learn and help them apply these ideas in their teaching, ideas like active learning and formative assessment (using testing to promote learning rather than just grade students). Our committee created the National Academies Summer Institute for Undergraduate Education in Biology, generally referred to just as the Summer Institute, or SI, for short, in 2003. Probably our most significant achievement was persuading Jo Handelsman to take the major role in shaping the SI, which she and I codirected until 2012. Working with Jo was a great pleasure, and I learned a tremendous amount from her over these years.

Jenny Knight attended the SI in 2004. In the course of it we realized that we weren't following the precepts of the SI in our own teaching. So although we were naïve about educational research, we decided to do an experiment with our course. At the time, clickers (which are audience response devices, as I hope everyone knows by now!) were starting to become available, as a way to test the understanding of all the students and stimulate discussion in a large class. First, in order to assay our results, we developed a test that the students would take at the start of the course and again at the end, to measure the gains they had made in understanding the concepts we were trying to teach. For one semester, we used it to gauge the effectiveness of our old method of teaching, and then for the next two semesters we substituted about a third of the lecture time with active learning exercises: clicker questions, discussion, problem solving, and so on, and measured the learning gains again. To our surprise we found about a 30% increase in learning gains in both the active learning semesters (Knight and Wood 2005). In addition, the new approach totally changed the atmosphere of the class, as students became used to discussing questions in front of the group. So we were convinced that these innovations were effective, and I've been teaching this way ever since and trying to persuade others to do so too.

So much is easily accessible on the internet now, there's no need to pack students' heads with information; what's important is that we teach students how to learn on their own [...] (W.W.)

How Has College-Level Education Changed Since Then?

There's good news and bad news. When we started the SI in the early 2000s, most of the participants were completely naïve about this kind of research-based teaching, and pretty skeptical as well. For example, none of the participants in our early workshops had heard of Bloom's taxonomy, which is a measure of the conceptual level of understanding that instructors are aiming for and students are learning at. A lot of teaching in biology aims quite low on this scale, simply asking students to memorize factual information rather than achieving deeper conceptual understanding. In the succeeding years, there has been a tremendous change in the level of sophistication. Most of the incoming participants now are already using active learning and Bloom's taxonomy, and they are attending the SI to learn how to do it better. That's the good news.

But at the same time, I would guess that the majority of college-level biology courses are still taught the old way, with students sitting passively, listening to a lecture, and taking notes. Even though a lot of progress has been made, there's still a long way to go. Another problem is that if you ask instructors who have been through this type of program whether they are using active learning, they will say yes, but if you actually observe their classes, they're typically doing less than they think they are.

What Advice Would You Give to Someone Trying to Improve Their Teaching?

I would urge people to make use of all the great resources and workshops available now. Watch videos of people using active learning in very large classes. Read some of the excellent new journals tailored for biologists, publishing education research that is more accessible than the traditional education literature, such as *CBE-Life Sciences Education* (http://www.lifescied.org/). Take a look at the compelling metaanalysis published by Scott Freeman and colleagues in 2014, which analyzed over 200 studies comparing the results of active learning to traditional instruction and clearly demonstrated substantially greater learning gains in active learning classes (Freeman *et al.* 2014). At the upcoming GSA's The Allied Genetics Conference in July 2016, you could also attend the session on the "Vision and Change" report. Vision and Change is a grassroots effort that has become a powerful force in transforming teaching along the lines I've been describing, and I'm sure there will be useful information discussed in the workshop.

Bill is not only an excellent educator himself, he helped start a revolution across STEM teaching through his involvement with the National Academies Summer Institutes on Life Science Education.

- Rachelle M. Spell, Emory University

What Are Some Major Challenges for Educators at the Moment?

I think one major challenge is deciding what we should be teaching students, in our case about biology. Over the past 10 years we've made progress toward *how* to teach more effectively, but we're still grappling with *what* we should teach. Various efforts, like the AP Biology curriculum revision, Vision and Change, and the Next Generation Science Standards have drawn up lists of core biology concepts, and at the level of "big ideas" these lists agree pretty well; the question is which of the finer details should we be teaching? I think a consensus is emerging that it's more important to teach skills and an understanding of the practice of science than any specific biology content. So much is easily accessible on the internet now, there's no need to pack students' heads with information; what's important is that we teach students how to learn on their own and how to evaluate the evidence for what they encounter in the media.

A second challenge is what we could call exit assessment. How can we find out what students have really learned in the course of a biology major? There's a lot of demand for accountability by various stakeholders—employers, funding agencies, university administrators, and so on—who want to know what students know and can do when they graduate. One approach would be to develop broader concept assessments that test recent graduates on their conceptual understanding of biology in general (*e.g.*, Smith *et al.* 2008; Couch *et al.* 2015). But these assessments must be designed to test large numbers of students, and so they currently consist of mostly multiple-choice questions, which can provide only limited information about what students know and can do. Probably the best method for finding out how much students know would be individual exit interviews, but you can't do that with hundreds or thousands of graduates. An intermediate solution could be an assessment consisting of short-answer and essay questions, but then who's going to score all these exams? The answer could come from computer-assisted grading. This is still controversial, but there are already programs in use that are pretty good at evaluating answers to simple essay questions. So if we can improve computer-assisted scoring methods, we can ask more sophisticated exam questions that will give us more insight into what our majors have learned.

What Needs to Change in Science Education?

We need to get students more comfortable with using mathematics and quantitative thinking, especially in biology. We also haven't done a good job of teaching students about the practice of science; that is, what scientists actually do and how they do it. Students generally don't know where the facts in the textbook come from or how to judge whether something they hear about in the media is based on reliable evidence. One exciting recent effort that addresses this problem is the development and dissemination of course-based undergraduate research experiences (CUREs), sometimes called discovery-based courses. These are typically small courses where students work in a team to investigate a question to which the answer is not known, often related to the instructor's research program. So they are doing authentic research, and in the process they learn how science works. Such courses require more resources than more traditional classes, but many educators believe that at least one CURE should be required of all science majors.

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