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Bye-Bye Bio 101: Teach Science the Way You Do Science


Image Title: - Sue Townsend, UW-Madison University Communications; Paul Fetters for HHMI

University science education needs reform, and effective methods are already known. Yet for years, many scientists and educators have actively resisted changing their teaching methods. Now, a group of persistent reformers is raising scientists' awareness of successful approaches to science teaching and providing them with tools to implement those strategies in their own classrooms and institutions.

"There is mounting evidence that supplementing or replacing lectures with active learning strategies and engaging students in discovery and scientific process improves learning and retention of knowledge," writes lead author Jo Handelsman, Howard Hughes Medical Institute professor and plant pathology researcher at the University of Wisconsin-Madison, in a policy forum article published in the April 23, 2004, issue of the journal *Science*.

"It's the science community that needs to reform. We are calling for change from

within."

— Peter J. Bruns

Handelsman and her co-authors, including Peter J. Bruns, vice president for grants and special programs at the Howard Hughes Medical Institute, and Shirley M. Tilghman, president of Princeton University and a former HHMI investigator, argue that outcome assessments demonstrate that students taught this way have better problem-solving ability, conceptual understanding, and success in subsequent science courses, when compared with students who learned in traditional, passive ways, they say.

Additional co-authors of the policy forum article are Jim Gentile, dean and former HHMI program director at Hope College; William Wood, University of Colorado at Boulder; Diane Ebert-May, Michigan State University; Robert Beichner, North Carolina State University; Amy Chang, American Society for Microbiology; Robert DeHaan, Emory University; James Stewart and Sarah Lauffer, University of Wisconsin-Madison.

Numerous reports, including the American Association for the Advancement of Science's "Science for All Americans" in 1989 and "Bio 2010: Transforming Undergraduate Education for Future Research Biologists," issued in 2002 by the National Research Council and funded in part by HHMI, have called for a shift to scientific teaching, which is defined as using the techniques of science: asking questions, formulating hypotheses, designing and conducting experiments, collecting and analyzing data, and writing about the results. "Most scientists don't read reports on education, but they do read *Science*, so this was the place to reach our colleagues," Handelsman points out.

In some instances, this shift is happening. Pioneer reformers such as Handelsman are spearheading fundamental changes in the way scientists teach and undergraduates learn science. They are replacing lectures with inquiry-based classes and labs in which students learn by using the tools of good science: designing and conducting experiments, analyzing the results, and drawing conclusions based on evidence. And they are basing those changes to the curriculum on scientific evidence.

In other words, they are teaching science scientifically. And it's working.

But widespread reform has been slow in coming because many scientists are unaware of data that demonstrate the effectiveness of that approach, the authors of the *Science* article say. Some feel intimidated by the challenge of learning new teaching methods or fear that focusing on teaching will hurt their credibility as researchers.

"It's the science community that needs to reform," says Bruns. "We are calling for change from within."

Beyond examining the barriers to reform, the policy forum offers recommendations for accelerating change. A list of dozens of online

resources, including tested and proven labs and other activities, accompanies the paper.

"We need to dispel the notion that excellent teaching is incompatible with first-rate research," says Bruns. At research universities, the reward system—tenure, sabbaticals, pay raises and promotion—is based on success in research, he points out. "We need to encourage and reward excellence and innovation in teaching."

HHMI is among those leading reform efforts, through its HHMI Professors initiative. In 2002, the Institute awarded $20 million to 20 recognized researchers at universities nationwide to find innovative ways to make undergraduate science teaching mirror the methods and rigors of research science at its best.

If scientific teaching is going to replace lectures and "cookbook" labs in which the results are already known, the policy paper says that research universities and scientists must lead the way. The authors recommend:

Revamping introductory lecture courses to include active participation by students Teaching science graduate students how to teach and how students learn Changing the reward system at universities to reflect the importance of good teaching

For example, the University of Wisconsin-Madison—Handelsman's campus—has rewritten guidelines for tenure, sabbaticals, and merit pay raises to emphasize teaching. And the HHMI professor and her colleagues introduced a course there in which non-science majors develop hypotheses, design and conduct experiments, and interpret data.

"Initially, many colleagues were skeptical of it," Handelsman recalls. "Some raised their eyebrows when they passed a lecture hall filled with 120 students talking to each other, and one called it `biology for poets.' But when they saw the results, which included students flocking to enroll and evidence that the students were grappling with real science and tough problems, many became excited, and quite a few of them now teach the course."

The HHMI-supported program at UW-Madison also focuses on training scientists to teach. "We introduce them to the education literature to encourage them to become scientific teachers who demand data to make educational choices," Handelsman says. "We provide opportunities for them to practice teaching using methods that have been shown to help students acquire knowledge and learn to think and reason about science." She offers a mentoring course to help graduate students and postdocs supervise undergraduates in research more effectively. "We hope to send into the world a new generation of teachers who are committed to engaging undergraduates in science both in the classroom and the research lab," the HHMI professor explains.

"In addition to being a passionate call for action, we hope the *Science* article provides educators with a comprehensive, yet accessible, set of outstanding

materials that will help them start their own revolution," she says.

To give science faculty members at research universities the tools to do what the paper's authors recommend, an annotated collection of more than three-dozen online resources accompanies the policy paper. They include tested and effective teaching methods to reach diverse students, inquiry-based labs, web-based programs to enhance classroom teaching, experiments and data about teaching methods, assessment tools, and workshops for science educators.

The HHMI Professors and other innovators have started planting the seeds of change. The next step is to disseminate their ideas, products and practices, says Bruns. To help do that, HHMI is supporting a new peer-reviewed, web-based journal called *Cell Biology Education: A Journal of Life Science Education*. HHMI and the National Academy of Sciences also are sponsoring a summer institute at the University of Wisconsin-Madison, where 36 faculty who teach large introductory courses will develop new instructional materials that apply tested teaching methods. The course is co-chaired by three of the policy paper's authors: Handelsman, Gentile and Wood.

"Many students attend research universities because of the strength of the science being performed there, but they get turned off in introductory courses and never look back," says Bruns. "We need those bright young minds. We want to encourage more students to become scientists, and we want to send non-science majors into society knowing how to confront issues that require analytical and scientific thinking."

"To achieve scientific literacy in society, we need to teach people how science is done, which means engaging them in science, asking them to *be* scientists, as part of their university education."