Effective teaching: To be an effective educator, get active

Scientists from leading universities, the National Academy of Sciences, and the White House are calling for faculty to move from traditional lecture-based teaching to active learning strategies. Active learning gets students involved in finding, interpreting, and explaining course material. It's an evidence-based method with rewards for students and instructors. This article explores how—and why—faculty should incorporate active learning into their courses. **By Chris Tachibana**

Jenny Loertscher's Seattle University biochemistry students wander into the classroom, chatting and laughing. Ten minutes later, all 30 are in small groups, grappling with applied problems about lactate fermentation. Loertscher listens in, notes questions, and eventually moderates a class discussion of solutions. The discussion structure pushes students to articulate their assumptions and evidence. The class weighs the strengths and weaknesses of the arguments and the best ways to communicate them—good preparation for next week's exam.

This is what student-centered, active learning looks like. Students do the meaningful activity of gathering, organizing, analyzing, and interpreting information and explaining it to others. In instructor-centered lecture courses, professors do that work, often learning more than the students.

How active learning works

All active learning methods aim to turn students from passive note-takers into engaged scientific thinkers. Loertscher's technique is process-oriented guided inquiry learning (POGIL), initiated in Seattle University chemistry classes by **Vicky Minderhout Thorsell**. Other methods include case-based and problem-based learning, common in medical schools, and flipped classrooms, in which students watch video lectures as homework and work on problems in class. Implementing these approaches isn't easy but can be rewarding.

"Inquiry-based learning makes people uncomfortable," says Minderhout Thorsell. "You're guiding students toward conclusions so you don't directly answer questions, which can be frustrating for everyone." To understand how and why active learning works, she says, think of it as coaching. During a soccer practice, players are on the field, getting guidance from the coach. They don't sit on the bench listening and then work out later at home. "How can you learn to do science," asks Minderhout Thorsell, "if you don't practice it with others?"

Students in active learning classes complain about the blind-leading-the-blind feeling of discussing information they haven't yet mastered. Many appreciate, though, that they stay awake in class, have frequent interactions with faculty, and although initially challenged, ultimately learn more. "We say if you're not struggling, you're not learning," says Minderhout Thorsell.

By engaging students in class, professors give students more responsibility for their own learning. Active learning also provides opportunities for students to practice crucial job skills, including working in teams and solving open-ended problems. For faculty, active learning can make teaching more satisfying. "Since we spend a lot of class time building scientific arguments and communicating them," Loertscher says, "I can ask higher-level exam questions. The students expect them and know I'll demand rigorous answers." Don't expect higher student evaluation scores, though. Loertscher says that after switching from traditional lectures to inquiry-based classes, she got more strongly positive and negative comments, but overall, her average student evaluations didn't change.

The case for active learning

So why switch from instructor-centered to student-centered methods, especially when tenure and promotion focuses on research instead of teaching? "Evidence," says **Jennifer Frederick**, executive director of the Yale University Center for Teaching and Learning. An extensive body of literature supports the effectiveness of active learning over traditional lectures for student exam performance and comprehension.

Susan Howitt, deputy head of biology teaching and learning, Research School of Biology, Australian National University, studies cell transporters in addition to her administrative and teaching duties. She understands the pressure to publish and the worry that changing teaching methods takes time; however, people who use a lecture-based teaching style are often convinced to change when they see evidence from their own classes, she says. "When faculty get detailed feedback from their own students, they usually see that students who seemed confident actually weren't that confident about what they knew. Even at the end of a course, many are confused about key concepts." continued>

Susan Howitt

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– Francis Jones

Frederick also points to a national trend toward scientific teaching, which encourages faculty to apply research principles to teaching. The concept is promoted by, among many others, **Jo Handelsman**, who is now in the White House Office of Science and Technology Policy (bit.ly/1KD197b). Scientific, research-based teaching makes sense to faculty whose science builds on prior evidence and advances the field through hypothesis-driven experiments and analysis, says Frederick. "Science faculty at elite research institutions are ambitious people who strive for excellence in everything," she says. "They're discovering that they can use their classes to test hypotheses about how students learn and to evaluate different learning methods."

Experience in research-based instruction is a professional asset for new faculty and postdocs entering a tough academic job market. And becoming a discipline-specific education specialist is an emerging career path, says **Francis Jones**, geophysicist and education specialist in earth, ocean, and atmospheric science at the University of British Columbia (UBC). "This is a growth area," he says, "as demand increases for postsecondary education." Education specialists, says Jones, are experts in their field and in teaching and learning in that field. They are most effective when they are integrated into a department as permanent support staff or faculty. Their job is introducing and sharing successful instructional strategies so that the department is using the most up-to-date, evidence-based teaching methods to help students progress.

For universities, a major benefit of active learning is lower failure rates and possible increased retention of science students, including underrepresented minorities and students with economic disadvantages. Active learning methods provide continuous feedback about student progress, so professors know early what concepts are difficult and which students are falling behind. They can make corrections immediately instead of waiting until after an exam. Active learning trains students in widely applicable skills such as problem solving, so it benefits students from disadvantaged backgrounds who have less science experience (bit.ly/1fLGpzD).

Transforming teaching: the first steps

For faculty introducing active learning into their classroom, experienced practitioners have two words: Get help. A large science education community is available to answer questions and offer advice about evidence-based teaching techniques. Guidance is available for all class sizes and subjects. Like Yale University, many institutions have teaching centers that can connect faculty with peers who are using active learning strategies and can give practical advice. University teaching centers also have expertise in evaluating scientific teaching methods. "We can help assess the impact of a teaching innovation," says Frederick. "We have the instruments and the analytical experience and know-how to use data to guide faculty to successful outcomes."

Howitt advises starting with a little reflection. Step back and think about what you want to accomplish, she says. A common concern when introducing student-centered activities is that they take time from content that seems critical to cover. Howitt says, this is a good time to ask: What are my goals for this class? What do students need to understand to go on in the field? What do I want them to remember years after the course? Look to the literature. In many fields, professional groups have published core or threshold concepts that students must master to progress.

Howitt and others advise starting small. Adapt your lesson plan to do a brief group activity, suggests Frederick, such as starting and ending lectures with a few minutes for the students to discuss a challenging question with a neighbor. Compare student performance on relevant exam questions to the previous year, analyze the results, and adjust your methods. "People who start with small changes," says Frederick, "are more likely to keep going and end up transforming the way they teach."

For laboratory classes and undergraduate research, Howitt has found that simply adding reflective activities enhances student learning. Even when students are in these settings that are designed for practicing science, she says, they still need prompting to get the most out of the experience. "Students often focus on a particular technique and don't think about the bigger picture," she says. "Having students reflect on why they are doing certain experiments and what they are learning as they go, for example with an online journal, helps them learn about experimental design and interpretation and where data comes from."

Faculty teaching workshops are an excellent introduction to innovative methods and need not be a massive time commitment. Annual meetings of organizations like the American Society of Cell Biology often include education sessions. More in-depth experiences are available through the Howard Hughes Medical Institute-funded National Academies Summer Institutes on Undergraduate Education.

Resources for innovative teaching

At UBC, the Carl Wieman Science Education Initiative (CWSEI) has been transforming science teaching since 2007. One specific goal is optimizing the use of education technology. Jones, who has been part of CWSEI from the beginning, says that technology enables moving content delivery out of the classroom, so in-class time can be used for practicing expert-like skills and applying knowledge. Technology also supports scaling-up effective educational practices.

The ideal teaching situation is one-on-one tutoring: an expert working directly with a novice. The close interaction allows the expert tutor to see how the student is thinking—the misconceptions, knowledge gaps, and challenges—and adjust. The adjustment is often for expert blindness: making assumptions and taking shortcuts in reasoning that leave the novice behind. Jones says that technical innovations like online course management programs or the flipped classroom allow faculty to use tutoring practices with many continued>

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– Jennifer Frederick

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The Australian National University
www.anu.edu.au

Massachusetts Institute of Technology
web.mit.edu

Seattle University
www.seattleu.edu

University of British Columbia
www.ubc.ca

Yale University
www.yale.edu

Additional Resources

L. Kober, *Reaching Students: What Research Says About Effective Instruction in Undergraduate Science and Engineering* (National Academies Press, Washington, DC, 2015).
www.nap.edu/catalog/18687/reaching-students-what-research-says-about-effective-instruction-in-undergraduate

Summer Institutes
www.academiessummerinstitute.org

TEAL
web.mit.edu/edtech/casestudies/teal.html

UBC Clicker Guide
www.cwsei.ubc.ca/resources/files/Clicker_guide_CWSEI_CU-SEI.pdf

students, to see how the students are thinking and react to support them.

Which brings us to personal response systems—clickers. These handheld wireless devices record individual student responses to in-class questions. Instructors can choose to display aggregated responses, for example as histograms, to make the collective thinking visible to the entire class. For many professors, especially in large classes, the first step toward active learning is introducing clickers or a low-tech option such as colored cards that students raise to indicate responses.

The UBC CWSEI has a guide for effective teaching using clickers. The key is moving beyond simple recall or comprehension checks to meaningful questions that encourage thinking about the solution instead of eliminating wrong answers. Students get the most out of clicker questions if they have time for individual reflection and group discussion before seeing the answer. Faculty can find effective clicker questions and get help with clicker strategies from the science education community and their university teaching center.

To deliver content and foster expert-novice and peer-to-peer interactions outside of class, most universities have an in-house course management system or access to commercial options. Jones says that educational information technology is still being refined. Standardization that will allow cross-institutional sharing of active learning resources will come. In the meantime, he says, technology is already enhancing professors' ability to see student thinking. "Undergraduate science classes with hundreds of students don't allow that optimal model of experts tutoring one or a few novices," he says. "But clickers, in-class worksheets, and content delivery with online quizzes using learning management platforms are examples of strategies that can make student thinking visible on a large scale."

Persevere: It's worth it

Education reform isn't easy. Faculty and students are comfortable with the traditional lecture format. However, instances of active-learning course transformations, often led by physics faculty, are easy to find. An inspirational example from the Massachusetts Institute of Technology (MIT) shows the rewards for students, faculty, and the university. **John Belcher**, physics professor, tells the story. "At MIT," he says, "introductory physics is required for all students, even business and linguistics majors." The class had an infamously high failure rate and terrible attendance, which motivated a revolutionary change from traditional lecture format to technology-enabled active learning (TEAL).

TEAL is a blended approach of lecture and hands-on activities, says Belcher, who admits implementing TEAL was a varsity-level move. "It was a major, six-year effort," he says. It succeeded because addressing the failure rate was a high priority for MIT leaders, who supported Belcher and his team while they "worked out the kinks." Belcher had seen Student-Centered Active Learning Environment with Upside-Down Pedagogies (SCALE-UP) classrooms at North Carolina State University with technology and seating designed to support active learning. Substantial external and university funding was available to SCALE-UP a physics classroom. Belcher notes that being married to Lori Breslow also helped. She holds a Ph.D. in communication and culture and was director of the MIT Teaching and Learning Lab, which helped assess, develop, and demonstrate the value of TEAL. Now, after 13 years, failure rates are down, attendance is up, 800 students a year experience the TEAL approach to physics, and Beal has received national recognition for his work (bit.ly/1eV4L9d). Course materials are standardized, maximizing the time faculty have for interacting with students. Volunteer peer assistants who took the course themselves help guide students through the new format.

"When I just lectured to 200 or 300 students, it wasn't fun, it was a performance," says Belcher. "It's a lot of fun to teach in an interactive classroom—and especially the younger faculty agree." Not everyone has the time and resources to completely transform a course, though, so Frederick has a simple rule about introducing active learning: "Start simple. We suggest a '10% rule,' meaning take small steps and work on a little bit of the class at a time. It's just like experimental science. You don't usually change all the variables at once."

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