SPECTRUM MASSACHUSETTS INSTITUTE OF TECHNOLOGY



# TEAL Teaching

## Technology Enabled Active Learning (TEAL) is transforming physics education

The scene: the d'Arbeloff Studio Classroom at MIT, which instead of standard-issue academic seating features 13 round tables with chairs.

*A team of students in the TEAL classroom. From left: Jennifer Wong, Danielle Wen, Asst. Prof. Eric Hudson, and Rayal Johnson. (Photo: Ed Quinn)*

At the tables, first-year students are looking on as lecturer Peter Dourmashkin, a physicist, puts up equations and diagrams on one of the room's white boards. His figures relate to how you define the elastic properties of, say, a beam or girder of known make-up, length and shape. As he writes, Dourmashkin also talks about the physics of how such structures deform under pressure.

He stops to ask a question: "Who can explain why an I-beam is shaped the way it is?"

The same scene, 20 minutes later: the students, working in groups of three, are briefly depressing long aluminum rulers mounted bridge-like between two small wooden blocks, then peering at the jagged plots that show up on their laptops — figures reflecting input from instruments that are measuring the frequency and amplitude of the rulers' bounces.

So is this a lecture? Recitation session? Lab?

The answer: all of the above. These students are involved in one of MIT's most renowned, and sometimes dreaded, rites of passage, first-year physics. But instead of listening to a lecture in a big hall, they're learning the same material in a new way.

The approach is Technology-Enabled Active Learning (TEAL). And while it draws heavily on approaches developed elsewhere, taken as a whole TEAL is unique.

### Grasping The Concepts

The new approach reflects MIT's effort to overcome certain challenges involved in

teaching first-year physics. There's a high likelihood, though, that in time it will find a place not only elsewhere at MIT but in other universities, too.

*Physics Prof. John Belcher spearheaded the creation of TEAL teaching. (Photo: Ed Quinn)*

Why the need for TEAL? According to John Belcher, a physics professor who not only leads some TEAL classes but spearheaded the approach's creation, it reflects the realities of teaching physics. Entering MIT students, he says, have good math skills, and so are well equipped to handle the problem sets they'll be handed in first-year physics. But they often have a tougher time grasping the concepts involved.

Example: "Say you have a wire ring sitting in a magnetic field," says Belcher. "If a current starts to flow through that ring, a torque will develop on the ring whose net effect is to make the axis of the ring align with the magnetic field in which it sits."

In other words, the ring will turn — and if they know a few facts, physicists and others can reliably predict which way it will turn. But because electricity and magnetism represent invisible, and for many, somewhat mysterious forces, it can be hard to teach even MIT students to make such predictions correctly.

"Eric Hudson, a TEAL faculty member, was lecturing on this phenomenon," says Belcher, "and gave what I thought was a very clear description of why these systems behave as they do. Then he asked the students to predict the outcome of an actual experiment, and most of them still couldn't tell which way the ring would turn."

Belcher says the students weren't at fault. "This is subtle stuff," he notes. But it's also a vivid indicator why lectures alone can't always fully convey some concepts.

## Beyond Chalk And Talk

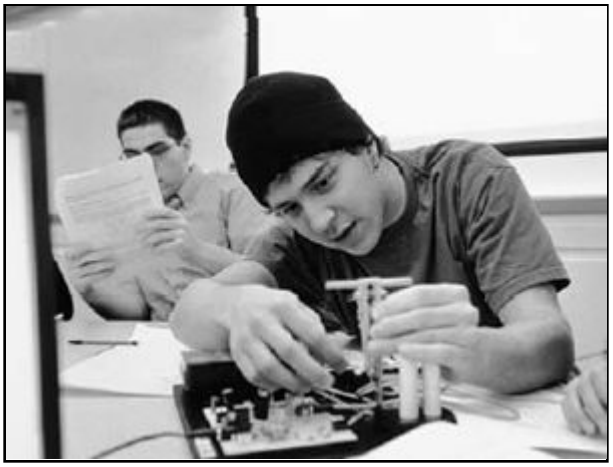
TEAL is designed to solve that problem. The new approach does include lectures, though these happen in relatively short spurts. But it also involves animation that lets you "see" things like magnetic forces at work. (In the TEAL classroom, the videos appear on not one but eight large screens.) Other features include:

- desktop experiments that relate directly to a specific day's topics;
- a Web-based check-in system that lets a class's leaders tell if individual students are doing the reading, and also identify those concepts that may be most confusing prior to class;
- teaching assistants who help students solve problems and do experiments with input from Physics Demonstration Group members; and
- a set-up called the personal response system (PRS) that lets students use TV clicker- like devices to "vote" anonymously on various descriptions of a concept, offering near-instant feedback on how well lessons are taking. (Thus, if a day's topics include the concept that every action generates an equal and opposite reaction, the question might be, "When a Mack truck hits a Volkswagen, which experiences the most force?")

**THESE FEATURES, ALONG WITH THE CLASSROOM ITSELF, WERE MADE**

**POSSIBLE WITH SUPPORT FROM THE iCAMPUS EDUCATIONAL TECHNOLOGY INITIATIVE, THE MIT-MICROSOFT ALLIANCE, AND THE d'ARBELOFF FUND FOR EXCELLENCE IN MIT EDUCATION - THE LAST NAMED FOR FORMER MIT CORPORATION CHAIRMAN ALEX d'ARBELOFF, AND HIS WIFE, BRIT.** But does it all work?

Belcher and his colleagues, including an expert on scientific education from Israel, probe that issue using several techniques. Among them: giving students in both the TEAL classes and traditional lecture hall-recitation classes special tests before and after the semester.



*Bill Walsh says his favorite features of TEAL are both electronic and human interactions. (Photo: Ed Quinn)*

TEAL students, says Belcher, make gains nearly double those of their counterparts in standard classes — a result similar to those in interactive classes at other universities.

The new approach especially helps students grasp tricky concepts. "In terms of quantitative problem-solving," says Belcher, "research has shown that students in both settings do about equally well. In terms of the concepts covered, the TEAL-like groups do far better."

The physicist says his group can't pinpoint which features of the new approach are most critical. He adds, though, that TEAL's interactive aspects are clearly key.

## Student Comments

Comments from students tend to back him up. Sophomore Bill Walsh, who took the TEAL course last year, says he liked both the electronic and human interactions. "It's pretty easy for me to get distracted in lectures," says Walsh, an electrical engineering/computer science major. "In TEAL," adds the Iowa native, "the professors are walking right up to your table, and you're also punching the buttons on the PRS clickers, so you're constantly engaged."

*Sophomore Mubarik Imam favors the TEAL program design. (Photo: Ed Quinn)*

The effects of student input on the TEAL program's design impressed sophomore Mubarik Imam, an aero/astro major. "If students felt an experiment wasn't as well integrated with the lecture as it could be," says the resident of Pakistan, "the professors would do things differently in future classes." Such observations help confirm for Belcher that his group is headed in the right direction.

What was it, though, that turned a faculty member who made his mark as an astrophysicist into an educational innovator?

"I was brought up in West Texas, where football ranks much higher than calculus," notes Belcher. "When I went to Rice, my freshman year was pretty rough." While essentially all of today's entering MIT students have had calculus, he adds, many still find physics challenging, and he'd like to help them if he can.

Belcher has also taught first-year physics in a lecture hall with 700 students. And though his listeners at the time gave the class high marks, he found it at best a mixed experience — in part because some first-year students always seem to cut physics lectures.

*A team of students works together on an experiment. (Photo: Ed Quinn)*

Then there's his research history, which included a stint as lead scientist on the Neptune phase of the Voyager spacecraft's interplanetary venture. A key lesson he learned then about presenting scientific information: images help.

"At our press conferences," he says, "when the people with pictures were presenting, the reporters would pay rapt attention. Then I'd stand up with my black-and-white line graphs, and suddenly a lot of the reporters would decide they needed to go to the bathroom."

## Physics Imagery

In fact, it was the idea of capturing key physics concepts in images that first spurred Belcher to focus on new modes of education. His area of specialization is electricity and magnetism. Thinking mini-movies would help students grasp concepts in that area, Belcher enlisted the aid of Mark Bessette, an MIT animation specialist, and the resulting videos are now a key part of the TEAL classes on electricity and magnetism. But as he learned of teaching innovations elsewhere, he expanded his plans. TEAL is the result.

The approach has generated widespread interest at MIT. Robert Redwine, dean for undergraduate education, says, "we're seeing more and more educational efforts that emphasize actively engaging students." TEAL, he adds, is a vital part of these efforts.

Meanwhile, a TEAL classroom has been created in the new Stata Center for Computer, Information, and Intelligence Sciences (though the room's opening is being delayed, in part because of a shortage of funds to equip it.) The MIT Sloan School, too, plans a TEAL unit in its proposed new complex.

Belcher and his colleagues, who speak about TEAL at national and international meetings, report that there's a lot of interest outside MIT. And while he won't hazard a guess about how broadly TEAL might spread, Belcher thinks it, or approaches like it, have great potential.

"Interactivity is the wave of the future," he says. "The more you can keep students engaged, the more likely they are to learn a subject well."

*— Richard Anthony*

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