Eric Mazur could barely contain his excitement. His teaching evaluations had just come in, and they were glowing.

He was still untenured, an associate professor of physics and applied physics at Harvard University. Eager to share his good news, he phoned his friend and mentor, Albert Altman, then a professor of physics at the University of Massachusetts at Lowell.

His students, Mr. Mazur crowed, had rated him about as highly as they could.

An uncomfortable silence hung between them.

"Eric," Mr. Altman finally said. "This is the kiss of death."

That conversation, some 25 years ago, was a clarifying moment for the Harvard professor. Conventional wisdom for a young, early-career faculty member is that good teaching won't get you very far. The incentives, particularly at research-oriented institutions, favor scholarship, and tooting your horn about how good you are in the classroom won’t exactly burnish your tenure bid.

Mr. Mazur’s career since then has defied those truisms. He’s become an academic celebrity, crisscrossing the world as an evangelist for improving teaching, mostly by lecturing about the need to end the lecture.

His most popular speech is a story of personal awakening: how he once thought he was an excellent teacher, became aware of his failures in the classroom and, by researching how his students learned, reinvented his courses. By framing his story as a confession, he gives voice to the anxieties that many of his fellow professors feel about their own teaching. He has been a key player in the effort to transform how science is taught, which is part of a broader debate about the flaws and virtues of the lecture, one of higher education’s most beloved, reviled, and enduring institutions. That argument, in turn, elicits deeper questions about professorial expertise, academic rigor, and who, in the end, is responsible for student learning.

Mr. Altman, as it turns out, didn’t have to worry about how his friend’s devotion to teaching would hurt his career. But his advice carried a second warning that Mr. Mazur didn’t grasp at the time. Teachers who think they’ve figured everything out risk becoming intellectually complacent. And that surely is the kiss of death.

The signals Mr. Mazur received as a young professor pointed to one conclusion: He rocked.

His lectures were clear and well received. His students could solve complex problems about rotational dynamics by calculating triple integrals.
His serene confidence was shaken by an unusual source: the Force Concept Inventory, a test of basic understanding of Newtonian physics, which was then making the rounds among physicists.

Mr. Mazur had heard about the test’s results at other colleges. Students generally showed a poor grasp of underlying scientific principles, whether they took seminars or large lectures, were taught by award-winning instructors or by graduate students, or attended elite institutions or less-selective ones.

Mr. Mazur was sure his students were different. This was Harvard. And he was a terrific teacher, after all.

Then he tested them.

What he found out unsettled him. The results showed that the majority didn’t understand the fundamentals of Newtonian physics, a subject they’d covered in the second week of the semester.

He retested them at the end of the course and they didn’t fare much better. The class average went up eight points, from 70 to 78, on a 100-point scale.

Struggling to understand the results, Mr. Mazur devised an experiment. On a midterm, he included two questions about circuitry. One was traditional and came from a textbook; it tested students’ ability to identify and carry out the appropriate calculation. The other was word-based and conceptual.

He thought the conceptual one would be simple, taking about 30 seconds to answer. Instead, he says, his students panicked. One of them filled six pages with everything he knew about circuits and currents in the hopes of stumbling across the right answer.

The students fared better on the calculation-based question. Mr. Mazur realized what he had really been teaching them: to memorize formulas.

Suddenly, other warning signs came into focus. He thought back to the people who told him they’d aced physics in school but never really understood it. He remembered the despairing comments scribbled on his otherwise stellar teaching evaluations. The subject is boring, some students wrote. Physics sucks.

Mr. Mazur reflected on how he had come to learn physics. It wasn’t during lectures, when his professors would turn their backs to the students and solve problems on the board. That was how he taught, too.

No, it was in his third year, when he worked in a lab, designing and carrying out experiments, that he came to understand and appreciate the subject. "I learned physics through apprenticeship rather than through courses," he says. "That’s when I discovered the joy of science."

Joy is not a word that often describes the lecture. But this method of teaching has come to arouse passions in an increasingly pitched and moralistic debate.

Critics, like Mr. Mazur, favor approaches that demand more classroom participation from students. In their view, students need to do more than listen during class; they must actively grapple with the subject matter, whether in small groups, by responding to questions using clickers, or through other exercises.

One scholar likened lectures to bloodletting, antiquated and not terribly effective. Another described lectures as "toxic" to student learning. When he was asked once about a large-scale analysis that showed greater gains in student learning from participatory strategies compared with lectures, Mr. Mazur wondered whether lecturing was an ethical teaching choice.

Defenders of the lecture counter that it has endured for hundreds of years for good reason: It works. To discard it, they say, is to acquiesce to the erosion of educational standards and let students off the hook for their own learning.
One humanities professor wrote last year that lectures work because they demand that students pay close attention, connect ideas, and understand how to build an argument.

For Alex Small, an associate professor of physics at California State Polytechnic University at Pomona, a lecture is only as passive as the listener. Students learn when they think about what they’re hearing and organize it into salient points. "This places the responsibility for learning on the student," he wrote on his blog, "whereas the modern zeitgeist places the responsibility on the instructor."

Lecturing, he says, serves another important purpose. It reaffirms the importance of expertise and allows students to see how an expert role-models the process of working through a problem.

In truth, though, the distinctions between lecturing and active learning aren’t always clear cut. Mr. Small, who has defended the lecture in The Chronicle, says that in his own courses he frequently stops to ask and answer questions.

"Should students do problem solving? Well, of course," he said in an interview. "If you’re only delivering information, you’re doing it wrong."

For his part, Mr. Mazur appreciates the lecture’s value. Some can be inspiring, and many are effective at dispensing information. But if students are supposed to learn, he says, they need to do more than simply listen. "Learning is not a spectator sport," he says.

After all, it’s not like you’d expect to pick up a dance step by watching a trained dancer, or learn to drive by observing someone else do it. You have to do something.

Why, then, does the lecture endure? Money is one reason. Lectures are inexpensive for institutions, allowing hundreds of students to be assigned to one faculty member.

Custom is another. Professors and students can each walk away from a lecture convinced they’ve gotten something out of the exchange, even if they haven’t. Mr. Mazur often likes to cite education research suggesting that students overestimate how much they learn from a smoothly delivered lecture.

"The lecture creates the perfect illusion," he says. "As the primary vehicle for teaching, it’s completely outmoded."

Confronted with his classroom failures, Mr. Mazur needed an alternative way to teach. It came to him by accident.

He was explaining a question on the Force Concept Inventory that about half of his students had gotten right. It asked them to compare forces that a car and truck exert on each other when they collide. He scribbled equations on the board but could tell from their faces that his students were lost. To him, the answer was simple. According to Newton’s third law, the forces were equal. He tried to explain again. No luck.

His despair mounting, Mr. Mazur told them to discuss their answer with a neighbor.

The tenor of the room changed. The students grew animated and the staid lecture hall began buzzing.

Mr. Mazur has developed an entire method around that experience. At its core, peer instruction requires students to learn, typically from a brief lecture, about core concepts, which they apply to problems and explain to their fellow students. It’s a simple way to get them to participate actively within the construct of a large lecture.
He has studied the effect on his students. Three years after switching to peer instruction, their learning gains on the Force Concept Inventory over the semester had doubled, from eight points, when he lectured, to 16. Four years after that, his students’ increase in conceptual understanding had tripled over the original group’s gain.

"I’d been fooling myself for many years thinking I was an effective professor," he said in a lecture at the University of Maryland at Baltimore County that he gave in 2009 and that has been viewed online more than 145,000 times. "But it was a house of cards."

His narrative of discovery has struck a nerve.

It is a staple of his lecture, "Confessions of a Converted Lecturer," that has helped turn him into an academic celebrity. His message, that professors must move away from the lecture, is one that some faculty members are reluctant to embrace. But he’s been asked to deliver more than 1,100 talks about teaching since 1990.

Mr. Mazur tailors his pitch carefully. People don’t like to feel pushed or told that what they’re doing is wrong, so he grounds his talk in his own experience. "I essentially make a fool of myself," he says.

The demand for his speeches also reflects a hunger for advice about teaching. "Deep down," he says, "everybody realizes that there are huge failures in the system."

Harvard, too, enhances his influence. It is supportive of teaching in general and of his work in particular, he says. The institution also provides him with a perch to spread his message and bypass his audiences’ resistance. If students as well prepared as Harvard’s aren’t learning through traditional methods like the lecture, his story suggests, then the same thing must be happening elsewhere.

A key moment in his talks is a demonstration of an exercise he does with his students. One of his standbys involves a basic concept about how molecules behave when they are heated. He explains it, then asks those in his audience to apply the idea to a new context, make a prediction, and persuade someone nearby that their answer is right.

### How to Remake a Course From the Ground Up

**Eric Mazur has crusaded for decades against the lecture, favoring an alternative method called peer instruction.** Three years ago, he went back to basics and designed a new physics course for nonmajors. It emphasizes team-based projects, uses positive peer pressure to motivate students, encourages cognitive growth and risk taking, and harnesses the social aspects of learning. Here are how three familiar features of a typical course get a makeover:

**Readings**

Students read material before class on an online platform called Perusall, which Mr. Mazur and his colleagues developed. Students post comments on the reading and respond to one another’s annotations, and these comments drive the next class.

**Homework**

To answer each problem, students do four things: articulate the problem in their own words, devise a plan to answer it, execute it, and evaluate how well it worked. They complete the problem sets alone before class and work in teams during it to correct errors. They are not graded on how correct their answers are but on their effort and their accuracy in judging how well they understood the problem.

**Exams**

There are none, but students do complete five hourlong "Readiness Assurance Activities" during the semester. In the first half-hour they solve the problems alone, they can consult the internet but not one another. In the second, they go over the problems again, this time with their teams. Their scores reflect individual mastery and collective contribution.
The effect can be galvanizing. Lynda A. Murphy, director of the Office of Teaching and Learning with Technology at Texas Woman’s University, recently brought Mr. Mazur to her campus in Denton after a year and a half of effort. She had been encouraging her colleagues to use techniques that prompt students to apply what they learn. Mr. Mazur, she says, had the scholarly gravitas to get instructors to see these methods’ value and try them.

"Everyone in the room was buzzing," she recalls. People were pounding on desks, trying to persuade one another that their answer to the thermodynamics question was correct, she says. "It was hysterical."

Mr. Mazur has visited more than 40 countries delivering presentations like this, and awareness of the kinds of strategies he advocates is growing in his field.

Close to 90 percent of physics faculty members said they had heard of research-based teaching strategies like Mr. Mazur’s, according to a 2012 study. A similar percentage had used these practices, and, among those, nearly two-thirds stuck with them.

Peer instruction is regularly cited in grant proposals and papers, both in physics and beyond. Over a recent lunch, Mr. Mazur unholstered his iPhone to run a search of scholarly citations of the term. The last time he checked, there were about 1,000 references to peer instruction, he said. His expressive eyebrows rose. "Wow," he said. Today there are more than 9,000.

Even now, Mr. Mazur remains keenly aware of the academic hierarchy that separates researchers and educators. He is adamant about maintaining his productivity as a researcher. Next year, he will serve as president of the Optical Society, a disciplinary group. His lab employs some two dozen researchers, most of whom work on projects involving short laser pulses and black silicon (he maintains a separate, and smaller, project on education research).

Still, being a teaching evangelist has proved lucrative. He and two partners developed software called Learning Catalytics, a cloud-based assessment system, which they sold to Pearson in 2013 for a reported $10 million. And in 2014, Mr. Mazur won the inaugural $500,000 Minerva Prize, a no-strings-attached grant recognizing his work in the classroom.

But every evangelist needs an audience of doubters to convert. Mr. Mazur estimates that the vast majority of faculty members are still content to lecture, and he likens changing the habit to moving a mountain. His gut feeling, he says, is that the share of professors who still lecture is somewhere around 95 percent. "Maybe I’m underestimating," he says.

Mr. Small, of Cal Poly, disagrees. It has become almost obligatory, he says, for physics professors to talk up the importance of active learning instead of lecturing. Even though a method like Mr. Mazur’s has become widely accepted, says Mr. Small, "people will often respond as though it’s revolutionary."

Even as peer instruction became widely adopted, Mr. Mazur was restless for change.

In studying data on his students, one point bothered him. Although peer instruction produced gains in conceptual understanding, his students’ sense of competence, or self-efficacy, dipped. It wasn’t as bad as in traditional courses, he says, but it was still a decrease.

"I felt crushed," says Mr. Mazur. He thought back to how he once felt as a 5-year-old in the Netherlands, where he grew up. His grandfather gave him a book about astronomy that captivated his imagination. When he entered Leiden University, he declared his major in that subject but dropped it six weeks later. The big questions that once animated him had been replaced by the drudgery of equations about star positions.

He wanted to help his students regain that sense of wonder. Peer instruction did little more than make the best of an inherently flawed model, he realized. "I’d taken something broken, the lecture," he says, "and tried to make it better."
He decided to build a course from scratch. After persuading his dean to let him take time off to rethink his teaching, he dug into education research and took a tour of other campuses to study what they were doing. He concluded that two things needed emphasis: students’ motivation and the social dimensions of education.

The result is Applied Physics 50, a yearlong course designed to fulfill physics requirements for majors in other science disciplines. A few universities are adopting the model on their own campuses.

Project-based learning is the center of the new course. Students work in teams. Many projects have low-stakes competitions attached to them, like constructing the most secure safe by using magnets as locks. Other projects have an explicit social benefit, like building musical instruments for an orchestra for poor children in Venezuela.

If peer instruction forced students to participate in class, the new course makes them take it over. Professors are often urged to place more onus for learning on students; the advice is that they should be a guide on the side instead of a sage on stage. In his new course, Mr. Mazur has moved himself far offstage; he missed about 40 percent of the meetings this past semester. Class just rolls on without him.

During a recent visit, students huddled around tables near whiteboards. They designed spectrometers, figuring out which lenses had the right focal length. They chose materials and argued over dimensions. Teaching assistants walked through the room, dispensing advice here and there. "Don’t just go off and build," one said. "Draw up a plan."

Mr. Mazur reconceived homework for the course, too. Students aren’t scored strictly on the accuracy of their answers but on their effort and how well they evaluate their work. If one of them skips a problem set, the score for the entire group suffers. Peers, Mr. Mazur says, are a far greater source of motivation than a professor.

His syllabus dedicates two paragraphs to the virtues of failure. Students are warned that some of their scores may be lower than what they’re used to. They should see failures, he writes, as "learning opportunities, not negatives, as steppingstones to success."

Repeated failure, as he has learned, is necessary for success.

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