The University of British Columbia experiment

This is the account in *Peak : Secrets from the New Science of Expertise* by Anders Ericsson and Robert Pool (2016, London: Bodley Head), pages 243 – 247. Ericsson is Professor of Psychology at Florida State University and is internationally recognized as a leading researcher on the psychological nature of expertise and human performance.

It is based on Deslauriers, L, Schelew, E and Wieman, C (2011) *Improved learning in a large- enrollment physics class Science* 332, 862-864

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Carl Wieman, who won the Nobel Prize in Physics in 2001, has made a second career out of working to improve undergraduate science education. Using part of his Nobel Prize winnings, in 2002 he created the Physics Education Technology Project at the University of Colorado, and later he established the Carl Wieman Science Education Initiative at the university of British Columbia. In all this he has been driven by the conviction that there is a better way to teach science than the traditional fifty-minute classroom lectures. And this is what he and his two colleagues set out to demonstrate in that bastion of traditional teaching, the freshman physics course.

The class at UBC had 850 students in three sections. It was a hard-core physics course, aimed at first year engineering majors, with the physics concepts taught in terms of calculus and the students expected to learn how to solve math-intensive problems. The professors were well regarded for their teaching skills, with years of experience teaching this particular course and good scores on their student evaluations. Their method of instruction was relatively standard: three fifty-minute PowerPoint a week given in a large lecture hall, weekly homework assignments, and tutorials where the students would solve problems under the eye of a teaching assistant.

Wieman and his colleagues chose two of the course's sections, each with about 270 students, as their testing ground. For the twelfth week of the second semester, one of these sections would continue with instruction as usual, while the other would be presented with a completely different way to learn about electromagnetic waves. The students in the two sections were about as alike as they could possibly be: the average scores on the two midterm tests the students had taken up to that point were identical between the two classes; the average class scores on two standardised tests of physics knowledge given during week eleven were identical; the class attendance rates during weeks ten and eleven were identical; and the assessed levels of engagement during weeks ten and eleven were identical for the two classes. In short, up to that point the two classes had been essentially identical in their classroom behavior and how well they were learning about physics. This was about to change.

In the twelfth week, as the instructor of one section continued as usual, the instructor in the second section was replaced with Wieman's two colleagues, Deslauriers and Schelew. Deslauriers served as the main instructor and Schelew as his assistant. Neither of them had ever been in charge of a class before. Deslauriers, a postdoctoral student, has received some training in effective teaching methods and, in particular, the teaching pf physics during his time at the Carl Wieman Science Education Initiative. Schelew was a physics graduate student who had taken a seminar in physics education. Both had spent some time as teaching assistants. But together they had far less experience in the classroom than the instructor who was continuing to teach the other section during the week of the trial.

What Deslauriers and Schelew did have was a new approach to teaching physics that Wieman and others had developed by applying the principles of deliberate practice. For one week they had the students in their section follow a very different pattern than in the traditional class. Before each class the students were expected to read assigned sections – generally just three or four pages long – from their physics text and then complete a short online true/false test about the reading. The idea was to make them familiar with the concepts that would be worked on in the class before they came to the class. (To even things out, the students in the traditional class were also asked to do preclass reading during this one week. It was the only change made in how the traditional class was taught during the week.)

In the deliberate-practice class the goal was not to feed information to the students but rather to get them thinking like physicists. To do that, Deslauriers would first have the students divide into up into small groups and then post a "clicker question", that is, a question that the students answered electronically, with the answers sent automatically to the instructor. The questions were chosen to get the students in the class thinking about concepts that typically give first-year physics students difficulty. The students would talk about each question within their small groups, send in their answers, and then Deslauriers would display the results and talk about them, answering any questions the students might have. The discussions got the students thinking about the concepts, drawing connections, and often moving beyond the specific clicker question they'd been asked. Several clicker questions were asked during the course of the class, and sometimes Deslauriers might have the students discuss a question a second time, after he had offered them some thoughts to ponder. Sometimes he would offer a mini-lecture if it seemed that the students were having difficulty with a particular idea. Each class also included an "active learning task" in which the students in each group considered a question and then individually wrote their answers and submitted them, after which Deslauriers would again answer questions and address misconceptions. During the class Schelew would walk around among the groups, answering questions, listening to the discussions, and identifying problem areas.

The students were much more active participants in this class than in the traditionally taught class. This was demonstrated by the measures of engagement that Wieman's group used. Although there was no difference in engagement between the two groups during weeks ten and eleven, during week twelve engagement in the class taught by Deslauriers was nearly double what it was in the traditional class. But it was more than just engagement. The students in the Deslauriers class were getting immediate feedback on their understanding of the various concepts, with both fellow students and the instructors helping to clear up any confusion. And both the clicker questions and the active learning tasks were designed to get the students thinking like physicists – to first understand the question in the proper way, then figure out which concepts were applicable, and then reason from those concepts to an answer. (The instructor in the traditional class observed Deslauriers's class before teaching his own and chose to use most of the same clicker questions in his own class, but he did not use them to begin discussions, only to show the class how many students had gotten each answer correct.)

At the end of week twelve, the students in both class sections were given a multiple-choice clicker test to see how well they had learned the material. Deslauriers and the instructor in the traditional class had worked together to develop a test that they and the instructor of the third section all agreed was a good measure of the learning objectives of that week. The test questions were very standard. Indeed, most of them were clicker questions that had been used for a physics class at another university, sometimes with small modifications.

The average score for the students in the traditional section was 41 per cent: the average in Deslauriers's class was74 per cent. This is obviously a big difference, but given that random guessing would have produced a score of 23 per cent, when you do the math it turns out that the students in the traditional class, on average, knew the right answer on only about 24 per cent of the questions, compared with an average of about 66 per cent in the class designed to apply the principles of deliberate practice. That is a huge difference. The students in the deliberate practice class got more than 2.5 times as many right answers as those in the other class.

Wieman and his colleagues expressed the difference in another way, using a statistical term known as "the effect size". In these terms the difference between the performances if the two classes was 2.5 standard deviations. For the sake of comparison, other new teaching methods in science and engineering classrooms generally have effect sizes of less than 1.0, and the largest effect size observed for an educational intervention before this had been 2.0 – which was accomplished with the use of trained personal tutors.

Wieman got to 2.5 with a graduate student and a postdoc who had never taught a class before.

Notes

The approach closely follows that of Cognitive Acceleration adapted for a group of 270 university students as compared with a class of some 30 school students. The phases of the CA lesson map onto Wieman as follows:

- pre-reading with true/false online test (concrete preparation)
- small-group discussion of a clicker question with feedback and clarification (social construction)
- several questions treated in this way (social construction with several questions or several episodes of social construction)
- "active learning task" with feedback (cognitive conflict)
- instructors walking around among the groups, answering questions, listening to the discussions, and identifying problem areas (metacognition).

Ericsson and Pool refer to further work on redesigning science courses at universities using the approach developed by Wieman and his colleagues.