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OPINION

How We Should Be Teaching Math

Achieving 'conceptual' understanding doesn't mean true mastery. For that, you need practice.

By **BARBARA OAKLEY**
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One of my engineering students recently approached me with a mixture of anger and befuddlement, thrusting toward me a quiz sheet covered with red pen marks: "I just don't see how I could have done so poorly. I understood it when you taught it in class."

I smiled encouragingly, but inside I sighed. The semester was just beginning. I hadn't had time to disabuse the student's naïveté. He still thought that because he "understood" the material, he was all set.

I'm now a professor of engineering, but in my mid-20s I was an artsy language lover who had flunked her way through elementary-, middle- and high-school math and science. What I discovered when I started over at age 26—first tackling remedial middle-school math and then working my way toward a Ph.D. in systems engineering—is that a conceptual understanding only gets you so far.

Conceptual understanding has become the mother lode of today's approach to education in science, technology, engineering and mathematics—known as the STEM disciplines. However, an "understanding-centric approach" by educators can create problems.

Today's Common Core approach to teaching STEM is at least superficially appealing. The goal of placing equal emphasis on conceptual understanding, procedural skills and fluency, and application is laudable. But as with any new approach to teaching, the Common Core builds on the culture that's already there. And the culture that has long reigned in STEM education is that conceptual understanding trumps everything. So bewildered math teachers who are now struggling to teach the Common Core are leaning on the old thinking, which has it that if a student doesn't understand—in the "ah-ha," light-bulb sense of understanding—there's no way she or he can truly become expert in the material.

True experts have a profound conceptual understanding of their field. But the expertise built the profound conceptual understanding, not the other way around. There's a big difference between the "ah-ha" light bulb, as understanding begins to glimmer, and real mastery.

As research by Alessandro Guida, Fernand Gobet, K. Anders Ericsson and others has also shown, the

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development of true expertise involves extensive practice so that the fundamental neural architectures that underpin true expertise have time to grow and deepen. This involves plenty of repetition in a flexible variety of circumstances. In the hands of poor teachers, this repetition becomes rote—droning reiteration of easy material. With gifted teachers, however, this subtly shifting and expanding repetition mixed with new material becomes a form of deliberate practice and mastery learning.

True mastery doesn't mean you use crutches like laying out 25 beans in 5-by-5 rows to demonstrate that 5 × 5 = 25. It means that when you see 5 × 5, in a flash, you know it's 25—it's a single neural chunk that's as easy to pull up as a ribbon. Having students stop to continually check and prove their understanding can actually impede their understanding, in the same way that continually focusing on every aspect of a golf swing can impede the development of the swing.

I'm a big proponent of active learning in the classroom—allowing students to interact with one another, and with me, to experience that light-bulb-going-on effect. But I'm also fully aware that just because a student might think he understood an idea in a classroom doesn't mean that he *truly* understood the idea. It certainly doesn't mean the student will retain that idea. And it absolutely doesn't mean that he has mastered the idea.

My angry, befuddled student, and many like him in my class, went on to take quiz after carefully designed quiz—all on the computer, and all designed to help students get the practice that would allow them to gain true mastery. When the semester ended, and evaluations on the class came (with an average of 4.9 out of 5 for a 65-student class), one comment typified many: "I really enjoyed this technique. At first, I wasn't too sure about it. Then it was tedious. However, then I realized how well I was doing on the online quizzes and the in-class quizzes and knew that something must be working!"

Understanding is key. But not superficial, light-bulb moment of understanding. In STEM, true and deep understanding comes with the mastery gained through practice.

Ms. Oakley is an engineering professor at Oakland University in Rochester, Mich., and the author, most *recently, of "A Mind for Numbers: How to Excel at Math and Science (Even If You Flunked Algebra)," (Tarcher/Penguin, 2014).*