TRY THIS ON FOR SIZE

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As some of you may know, we are working on a book—*Teaching and Learning STEM: A Practical Guide*—which should come out in Spring 2016. In the course of writing it, we've collected a number of easy but powerful teaching strategies. See if any of these strike you as worth trying.

- ***After your students work through a calculation in class or homework, ask them to brainstorm reasons the result might be different if it were measured in a lab or plant.***

In a typical problem in a math, science, or engineering course, students are given information about a system or process and asked to calculate values of selected variables. They write equations, solve for the desired variables, and move on to the next problem. In research labs and industrial plants, on the other hand, determining variable values is only part of what goes on—usually the easy part. The harder and more interesting part is *troubleshooting*—trying to figure out why things didn't go the way they were supposed to.

Consider occasionally asking students to troubleshoot in your courses. For example, have them speculate in Part (b) of a problem why measured variable values might fail to match values calculated in Part (a). Repeated practice in such exercises will train the students to think critically about possibilities expert engineers and scientists routinely think about, such as invalid or inadequate theories and models, faulty assumptions, mathematical and computational mistakes, and errors in gathering, analyzing, and interpreting data. The more students think about those things in their courses, the more likely they'll be to do it on the job.

- ***When you ask questions in class, don't stop asking as soon as you get the answer you're looking for.***

High-level thinking usually involves coming up with several ideas before finding a good one. Unless you're sure a question has only one right answer and there's only one way to get it, collect several responses instead of stopping at the one you had in mind, and then give the correct answer and discuss why incorrect answers are wrong. This practice can uncover and correct students' misconceptions, expand their arsenal of problem-solving strategies, and show them that avoiding premature acceptance of an idea can lead to better ideas and sometimes the best one.

- ***Bring in practicing professionals to talk about how they use course material.***

Many students tune out course material they don't think they will ever use after graduation, and they can be resistant or hostile to attempts to teach them professional skills such as communications, critical thinking, and teamwork. You can make all sorts of pretty speeches about how important those

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things are, but many students aren't buying it. Corporate recruiters and alumni are often pleased to visit classrooms and talk about their experiences, and students tend to take them seriously since they come from the "real world" the students are preparing to enter. Talk with the visitors ahead of time and suggest points you would like them to make about the usefulness of your technical course content and any professional skills you plan to stress.

- ***Collect "minute papers."***[1]

Stop your class with one or two minutes to go in the period and have the students anonymously answer two questions on a sheet of paper: (1) *What was the main point of today's class?* (2) *What was the muddiest point (most confusing point, your most pressing question)?* Stand at the door and collect their papers as they leave. After class, skim through the papers and compile common replies to each question. At the beginning of the next class session, if most students got the main point, compliment them and briefly restate it; if many didn't, go over it again. Then clear up the two or three most common points of confusion.

- ***Encourage students to send you links to pictures and videos that illustrate course-related concepts and phenomena.***

Students today tend to make extensive use of online materials and are skilled at finding them. Put that talent to work for you by offering two or three points on your next mid-term exam or homework assignment to students who find a good online resource that illustrates something you are teaching about. You'll have lots of takers (students will do a lot for two points), and you should get some excellent materials you can use whenever you teach that course again.

- ***Visit LearnChemE <www.learncheme.com/> or the AIChE Concept Warehouse <http://jimi.cbee.oregonstate.edu/concept_warehouse/CW.php> to find some new instructional resources for your course.***

The first resource is targeted specifically to chemical engineering, and the second one heavily targets chemical engineering but is expanding to cover other disciplines. Check them out—you might find an interesting screencast, simulation, or video you can show in class or as part of a flipped classroom assignment.

- ***Hold some virtual office hours.***

Instead of waiting—often in vain—for students to come to your office for help, designate times each week when you will be available to respond to emails, texts, or chat requests. You're guaranteed to hear from some students who for one reason or another will never visit your office, no matter how amiable and inviting you may be.

- ***Have students complete "exam wrappers."***[2, 3]

When you hand back your first graded exam, attach a questionnaire asking the students to reflect on how they prepared for the test, how well their approach worked, and what they might do differently in the future. This technique helps students take some responsibility for their grades and stands a good chance of improving their performance on future exams.

- ***Use "thinking-aloud pair problem solving" (TAPPS) to guide students through partially or fully worked-out examples.***[4]

At the start of class, ask students to get into pairs. Hand out a complex derivation or problem solution and have the pairs work through it in a sequence of short activities. In each activity, one student explains a portion of the derivation or solution, including the logic behind each step, and the other student asks questions if the first one says anything unclear and gives hints if necessary. Stop the activity after a short time—generally no more than three minutes—and call on students to report on their work. When the correct explanation has been forthcoming, tell the pairs to reverse roles and continue with the next few steps. Using a worked-out example takes the emphasis off routine calculations and allows students to concentrate on the reasoning behind each step of the solution procedure. This is the most effective technique we know for enabling students to come out of a class really understanding a derivation or problem solution, as opposed to thinking—usually mistakenly—that they understand it when they just watch you go through it in a lecture.

If you try any of these techniques, do it at least three times. Very few things in life work perfectly the first time, and if a technique doesn't go as well as you hoped it would, think of how you could improve it and try it again. By the third time, you should know whether it's a method you want to keep on using.

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