HOW TO TEACH (ALMOST) ANYBODY (ALMOST) ANYTHING

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It seems it's no longer enough for you to teach about the Navier-Stokes equations and potential flow past submerged objects. The ABET coordinator says that students in the fluids course have to be taught oral communications too, and the department head got inspired at some workshop and now wants to teach critical thinking in every course, including fluids. You argued at the faculty meeting that it's all you can do to get through fluids in the fluids course but got little sympathy, and it looks like there's no way out of it.

You probably have some questions at this point, like, *(a) Exactly what are those skills I'm supposed to teach? (b) Can they be taught* (as opposed to you either have them or you don't)? and *(c) How?* For an answer to *(a)*, we invite you to check out an article we wrote on learning objectives, teaching strategies, and assessment methods that address ABET Outcomes 3a–3k.[1] The answer to *(b)* is, yes. This column suggests some answers to *(c)*—how do you enable students to develop and improve a targeted skill, whether ABET-related or not? While we don't guarantee that the techniques we'll recommend will always work for all students, we're confident the results will be good enough to satisfy ABET and your department head, and—as long as your expectations are realistic—you.

1. *R.M. Felder and R. Brent, "Designing and Teaching Courses to Satisfy the ABET Engineering Criteria,"* J. Engr. Education, *92(1), 7–25 (2003),* <www.ncsu.edu/felder-public/Papers/ABET_Paper_(JEE).pdf>. *If you're not an engineering educator or you are one and just got back from the latest Mars expedition, let us explain that Outcomes 3a–3k are specified attributes engineering students in accredited programs should have by the time they graduate. They include the usual technical abilities but also such things as communication skills, the ability to work effectively in multidisciplinary teams, and an understanding of the professional and ethical responsibilities of an engineer.*
2. *N.E. Gronlund,* How to Write and Use Instructional Objectives *(6th Ed.), Upper Saddle River, NJ: Prentice-Hall, 2000. See also R.M. Felder and R. Brent, "Objectively Speaking,"* Chem. Eng. Ed., ***31*** *(3), 178–179, 1997,* <www.ncsu.edu/felder-public/Columns/Objectives.html>.

► *Write detailed learning objectives and let the students in on them*

Learning objectives (or *instructional objectives*) are explicit statements of what students should be able to do to demonstrate that they have learned what you want them to learn.[2] The objectives must specify directly observable actions (*list, explain, calculate, derive, model, critique, design . . .*). Verbs such as "*learn*," "*know*," "*understand*," and "*appreciate*" are unacceptable. You can't see students understanding something; to know whether or not they understand, you have to ask them to do something you can see that demonstrates their understanding. For examples, see *<www.ncsu.edu/felder-public/che205site/studyguide2.pdf>*, a study guide containing a subset of the learning objectives for the introductory chemical engineering course. Even if you don't know the course content, you should be able to convince yourself that if the students can do everything on those two pages, they have

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probably learned what the instructor wants them to learn in that part of the course.

Our first recommendation is to *write detailed learning objectives and give them to the students as study guides for exams and as guidelines for other assignments such as project reports and oral presentations.* Make sure your objectives cover all the skills you would like students to master, especially high-level skills (such as critical and creative thinking) and the ABET-mandated outcomes that have not been traditionally addressed in engineering courses, such as communication and lifelong-learning skills. When you are explicit about your expectations, the likelihood that your students will meet them goes up dramatically, especially if the expectations involve difficult or unfamiliar material.[2]

► *Teach skills before you assess them*

Take problem formulation as an example—another one of those ABET outcomes few of us ever thought about before they showed up in the Engineering Criteria. Suppose an objective in your fluids course states that the students should be able to make up (and solve) fluid dynamics problems whose solutions call for creative thinking. If you simply assign students to do that, most won't get what you're after and you'll see mainly problems that look like, "Given X and Y, calculate Z." That shouldn't surprise or disappoint you, since nobody ever taught them how to do what you're now asking them to do.

If, however, you *first explain and illustrate what you're looking for, then show several good and bad examples and have the students work in small groups in class to critique them, then give and grade two assignments that include the same task and perhaps show some submissions from students who got the idea*, you'll start seeing creative problems.[3] Doing all that would allow you to check off both problem formulation and critical thinking on the list of outcomes addressed in your course. You can do the same thing for, say, writing technical memos (communication and critical thinking), analyzing workplace case studies (professional and ethical awareness), or critiquing an engineering-related article in the popular press (professional awareness, communication skills, understanding the societal impact of engineering solutions, knowledge of contemporary issues, and lifelong-learning skills).

► *Use rubrics for grading*

Problem-solving and multiple-choice tests are relatively easy to grade, and if the grading system is rational, students should have no trouble understanding what they did wrong and why they got the grade they did. The same is not true of written project reports, essays, case study analyses, and oral presentations. When students just get grades and a few written comments as feedback, they may understand why they were marked down but may have little idea about how to do it better next time.

There's a better way. *Use a rubric to grade anything that involves subjective judgment on the part of the grader.* Decide on criteria you will use to evaluate the memo, report, or presentation (*e.g.*, technically accurate, complete, appropriately documented, well organized, well written, good visuals, sound theoretical analysis . . .); assign weights to each criterion; and—for a four-point rating scale—briefly summarize the attributes of a 1, 2, 3, and 4 for each criterion.[4] Then, *when you give students illustrative written products or oral presentations to critique in class, have them use the rubric individually and then compare their ratings, and then share your ratings with them. When you hand back their assignments, give them your completed rubric as well*—and watch how they improve on the next assignment. As with learning objectives, when a grading system is clear, the students are more likely to meet expectations.

► *If a skill is important to you, assess it*

Once you've communicated your learning objectives and assessment method for a particular skill, and you've provided examples and practice in applying the skill, then (and only then) is it legitimate to test the students' mastery of the skill—and at that point, you definitely should. Engineering students barely have enough time to keep up with their assignments; they don't have time to dig deeply into everything in all of their courses. If they are sure that something requiring effort on their part to learn won't count toward their grade, most won't bother to learn it. That's not laziness—that's rational behavior. The assessment drives the learning: *if a skill is important to you, assess it.*

Here's our challenge to you: (a) Pick a problem-solving or professional ("soft") skill that your students have always had trouble mastering; (b) write one or more learning objectives that list the things you might ask students to do to demonstrate mastery of that skill; (c) share the objectives with the students—if possible, as part of an exam study guide; (d) give your class examples of what you're looking for and several opportunities to practice the skill, in and out of class; and (e) assess the students' mastery of the skill (using a rubric if subjective judgment is involved) by asking them to do some of the things specified in the objectives. If you see better performance than you've ever seen (which we always have when we've done all that), consider making this strategy a permanent addition to your teaching toolkit. ❒

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3. *R.M. Felder, "On Creating Creative Engineers,"* Eng. Ed., ***77****(4), 222–227 (1987)*, <www.ncsu.edu/felder-public/Papers/Creative_Engineers.pdf>.
4. *You can see an illustrative rubric for evaluating student presentations at* <www.ncsu.edu/midlink/rub.pres.html>.

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