This one-page column will present practical teaching tips in sufficient detail that ChE educators can adopt the tip. The focus should be on the teaching method, not content. With no tables or figures the column should be approximately 450 words. If graphics are included, the length needs to be reduced. Tips that are too long will be edited to fit on one page. Please submit a Word file to Phil Wankat <wankat@ecn.purdue.edu>, subject: CEE Teaching Tip.

CHALLENGE PROBLEMS

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You just wrote a really interesting and relevant quiz or test problem and you start to solve it. A few hours later it dawns on you that although interesting and relevant, the problem is too long and/or too difficult to use as a test problem. What do you do with this lovely, but long, problem? You could use it as a homework problem, but unless some method is developed to motivate the students, many will give up when the going gets tough. As an alternative, make it a challenge problem with a suitable reward for students who successfully solve the problem.

In Spring 2012 I was teaching the junior-level separations course at the University of Canterbury in Christchurch, New Zealand. As part of the section on crystallization from solution the class was studying precipitation by adding anti-solvent. I developed the following practical and surprisingly difficult problem using published data[1] on precipitation of salts from water by adding methanol.

In a salting out experiment we dissolve NaCl into 1000 g water until it is saturated at 30 °C.

A. How many moles of NaCl are in solution?

B. How many moles of methanol need to be added to precipitate exactly ¼ of the moles of NaCl dissolved in Part A?

When I solved this problem, I found part B was clearly too difficult and too time-consuming for the quiz. Four factors make the problem difficult: 1. Data is reported using a combination of mass and molar units. 2. Data is presented in graphical form that has to be converted to digital form. 3. Addition of methanol decreases the moles salt/mole solvent, but increases the moles of solvent. As a result the amount of salt that will dissolve first decreases but may then increase. 4. The result is quite sensitive and small errors in reading the graph are multiplied. One student, who got the correct answer, commented, "By time I realized it was hard, I had spent several hours on it so I was determined to finish."

Since this problem covered the same objectives as the quiz but required deeper learning, it was offered as a challenge problem. Students who turned in a successful solution by 5:00 p.m. on Thursday received 100% on the quiz scheduled for noon on Friday and were excused from that quiz. Students turning in an incorrect solution were not penalized, but were expected to take the quiz. The problem was to be done in test mode—no consulting other students or academic staff. Since there is some error in reading the graph, the students needed a correct procedure and their answer had to be within ± 9% of the correct number of moles of methanol added.

Students in New Zealand are just as grade conscious as students in the United States. The chance to earn a 100 without taking the quiz was very motivating for many students. Out of a class of 61 students, 27 students (44%) turned in a solution and 11 (41%) passed. Successful solutions ranged from hand and spreadsheet calculations based on reading a series of equilibrium concentrations off the graph to rather elegant spreadsheet solutions that included a polynomial fit to the data. Since the solution had to be handed to me in my office, I talked to more students on Thursday than the entire rest of the semester combined. The general consensus of students who were successful was they spent more time solving the challenge problem than they would have studying for a quiz.

Good challenge and quiz problems both focus on course objectives. Challenge problems, however, should include course objectives that cannot be included in a test problem such as use of computer tools, solving complex multiple-step problems, and the value of persistence. Since the ability to evaluate one's own work is valuable although seldom taught, a good challenge problem will follow the old adage, "Every difficult problem has a simple answer, and it's wrong."

ACKNOWLEDGMENT

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REFERENCES

1. Lozano, J.A.F., "Recovery of Potassium Magnesium Sulfate Double Salt from Seawater Bittern," *Ind. Eng. Chem. Process Des. Develop.*, **15**(3) 445 (1976) ❐