Random Thoughts . . .

ANY QUESTIONS?

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Most questions asked in engineering classes follow one of two models:

1. "If a first-order reaction A → B with specific reaction rate 3.76 min^{-1} takes place in an ideal continuous stirred-tank reactor, what volume is required to achieve a 75.0% reactant conversion at steady state if the throughput rate is 286 liters/s?"
2. "Do you have any questions?"

While these may be important questions to ask, they don't exactly stimulate deep thought. "What's the volume?" has only one possible correct answer, obtained by mechanically substituting values into a formula. "Do you have any questions?" is even less productive: the leaden silence that usually follows makes it clear that the answer for most students is always "No," whether or not they understand the material.

Questions lie at the heart of the learning process. A good question raised during class or on a homework assignment can provoke curiosity, stimulate thought, illustrate the true meaning of lecture material, and trigger a discussion or some other form of student activity that leads to new or deeper understanding. Closed (single-answer) questions that require only rote recitation or substitution don't do much along these lines, and questions of the "Any questions?" variety do almost nothing.

Following are some different things we can ask our students to do which can get them thinking in ways that "Given this, calculate that" never can.

Define a concept in your own words

- *Using terms a bright high school senior (a chemical engineering sophomore, a physics major, your grandmother) could understand, briefly explain the concept of vapor pressure (viscosity, heat transfer coefficient, ideal solution).*[1]

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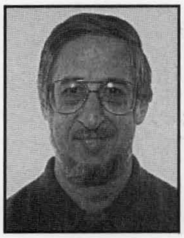

Explain familiar phenomena in terms of course concepts

- *Why do I feel comfortable in 65°F still air, cool when a 65°F wind is blowing, freezing in 65°F water, and even colder when I step out of the water unless the relative humidity is close to 100%?*
- *A kettle containing boiling water is on a stove. If you put your finger right next to the kettle but not touching it, you'll be fine—but if you touch the kettle for more than a fraction of a second you'll burn yourself. Why?*

Predict system behavior before calculating it

- *Without using your calculator, estimate the time it will take for half of the methanol in the vessel to drain out (for all the water in the kettle to boil off, for half of the reactant to be converted).*
- *What would you expect plots of C_B vs. t to look like if you ran the reactor at two different temperatures? Don't do any calculations—just use logic. Explain the shapes of your plots.*
- *An open flask containing an equimolar mixture of two miscible species is slowly heated. The first*

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[1] *Warning: Don't ask your students to give a comprehensible definition of something like τ_{xx} or entropy or temperature or mass unless you're sure you can do it.*

species has a normal boiling point of 75°C and the second boils at 125°C. You periodically measure the temperature, T, *and the height of the liquid in the flask,* h, *until all of the liquid is gone. Sketch plots of* T *and* h *vs. time, labeling the temperatures at which abrupt changes in system behavior occur.*[2]

Think about what you've calculated

- *Find three different ways to verify that the formula we just derived is correct.*
- *Suppose we build and operate the piping system (heat exchanger, absorption column, VLE still, tubular reactor) exactly as specified, and lo and behold, the throughput rate (heat duty, solvent recovery, vapor phase equilibrium composition, product yield) is not what we predicted. What are at least ten possible reasons for the disparity?*[3]

Brainstorm

- *What separation processes might work for a mixture of benzene and acetone? Which one would you be tempted to try first? Why?*
- *What are possible safety (environmental, quality control) problems we might encounter with the process unit we just designed? You get double credit for an answer that nobody else thinks of. The longest list gets a three-point bonus on the next test.* Once a list of problems has been generated, you might follow up by asking the students to prioritize the problems in terms of their potential impact and to suggest ways to minimize or eliminate them.

Formulate questions

- *What are three good questions about what we covered today?*
- *Make up and solve a nontrivial problem about what we covered in class this week (about what we covered in this class and what you covered in your organic chemistry class this month). Memory and plug-and-chug problems won't be worth much—for full credit, the problem should be both creative and challenging.*
- *A problem on the next test will begin with the sentence, "A first-order reaction $A \rightarrow B$ with specific reaction rate $3.76\ min^{-1}$ takes place in an ideal continuous reactor." Generate a set of questions that might follow. Your questions should be both qualitative and quantitative, and should involve every topic the test covers. I guarantee that I will use some of the questions I get on the test.*

I could go on, but you get the idea.

Coming up with good questions is only half the battle; the other half is asking them in a way that has the greatest positive impact on the students. I have not had much luck with the usual approaches. If I ask the whole class a question and wait for someone to volunteer an answer, the students remain silent and nervously avoid eye contact with me until one of them (usually the same one) pipes up with an answer. On the other hand, if I call on individual students with questions, I am likely to provoke more fear than thought. No matter how kindly my manner and how many eloquent speeches I make about the value of wrong answers, most students consider being questioned in class as a setup for them to look ignorant in public—and if the questions require real thought, their fear may be justified.

I find that a better way to get the students thinking actively in class is to ask a question, have the students work in groups of two to four to generate answers, and then call on several of the groups to share their results. I vary the procedure occasionally by having the students formulate answers individually, then work in pairs to reach consensus. For more complex problems, I might then have pairs get together to synthesize team-of-four solutions.

Another effective strategy is to put questions like those listed above into homework assignments and pre-test study guides, promising the students that some of the questions will be included on the next test, and then include them. If such questions only show up in class, many students tend to discount them; however, if the questions also routinely appear in homework and on tests, the students take them seriously. It's a good idea to provide feedback on their initial efforts and give examples of good responses, since this is likely to be a new game for most of them and so at first they won't know exactly what you are after. After a while they'll start to get it, and some of them may even turn out to be better at it than you are. This is not a bad problem to have.[4] ❐

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[2] *You will be amazed and depressed by how many of your students—whether they're sophomores or seniors—say the level remains constant until T=75° and then the liquid boils.*

[3] *Be sure to provide feedback the first few times you ask this critically important question, so that the students learn to think about both assumptions they have made and possibilities for human error.*

[4] *For more information on helping students develop creative problem-solving abilities, see R.M. Felder, "On Creating Creative Engineers,"* Eng. Ed., ***77****(4), 222 (1987) and "The Generic Quiz,"* Chem. Eng. Ed., ***19****(4), 176 (1985), and Chapter 5 of P.C. Wankat and F.S. Oreovicz,* Teaching Engineering, *McGraw-Hill, New York (1993).*