Teaching Philosophy

Cory M. Simon, Ph.D.

> Sometimes genius is anything but rarefied; sometimes it's just the thing that emerges after twenty years of working at your kitchen table.
>
> Malcolm Gladwell

I thoroughly enjoy teaching, and it is easy to find meaning in doing it. In addition, teaching can be self-beneficial: (i) I find legitimacy in the adage "the best way to learn something is to teach it", and (ii) teaching sharpens one's ability to formulate and explain ideas in a clear, concise, and captivating manner.

> Make things as simple as possible, but no simpler.
>
> Albert Einstein

My goals for student learning are for the student to think rigorously, be inquisitive, frame problems, and approach new problems in contexts that they have not exactly encountered in the classroom. This involves the reductionist approach of breaking a complicated problem into modules and making abstractions. After the reduced problems are well-understood, the students can link these coupled modules together and build complexity onto the simple abstractions.

A core philosophy in my teaching is to focus on instilling a deep *conceptual understanding* into my students rather than *procedures* for solving problems. Many students memorize and apply "recipes" to solve chemical engineering problems and exhibit only a shallow understanding of the governing equations or rationalizations of the procedures they apply. The consequence is that these students then cannot transfer their knowledge to solve the same problem in a different context or with a slight alteration; thus, such students lack true problem solving skills.

To help avert this phenomenon, I incorporate qualitative *concept questions* into homework assignments and short classroom discussions. For example, in the process of giving mock preliminary exams to first-year Berkeley Ph.D. students, almost all of the students successfully solved Problem 1:

Problem 1. Write an expression for the work required to isothermally and reversibly compress a gas from volume V_1 to volume $V_2 < V_1$. The gas obeys the van der Waals equation of state:

$$P = \frac{NRT}{V - Nb} - a\left(\frac{N}{V}\right)^2.$$

However, the students mostly failed to answer Problem 2, a conceptual question, without meticulously examining their mathematical expression obtained from the solution of Problem 1.

Problem 2. Consider the isothermal and reversible compression of a gas from volume V_1 to volume $V_2 < V_1$. Which gas requires more work to compress?
(i) an ideal gas
(ii) a van der Waals gas

Problem 1 can be solved with a recipe; Problem 2 cannot. If and only if a student *understands* isothermal compression and the molecular origin of the van der Waals equation of state, he or she can answer the qualitative, conceptual question in Problem 2 without writing anything on paper. By the way, Problem 2 is not fully framed; the answer depends on the initial conditions of the gas. *Discussion* of such qualitative questions among the students helps them discover ideas themselves and internalize them. Other example concept questions are "*Why* is there a point at which the Joule-Thomson coefficient changes sign?" and "Which is greater, c_P or c_V, and *why*?".

To further my concept-driven teaching, I judiciously choose the most minimal, illuminating example(s) to illustrate a given concept. Later, e.g. with progressively challenging homework problems, complexity can be built upon this foundation. I do have high expectations for my students. But, practically, there is a tradeoff between the volume of material that a teacher "covers" during a lecture and the intimacy with which the students understand and internalize those concepts. In the first exposure to a concept, complicated and voluminous examples can obfuscate the message and incentivize students to resort to identifying a procedure to memorize instead of *understanding* the concept the examples are intended to illustrate. My teaching style is to walk through a single, rich example in clear detail, pause to appreciate the logic underlying each step, and intuit and discuss the final result in words.

Finally, I foster inquisitiveness and the ability to frame problems by solving a familiar problem multiple times but under different settings. This can be done as a project or long homework assignment near the end of the course. Consider Problem 3:

Problem 3. The vapor phase reaction:

$CH_3COCH_3 \longrightarrow CH_2CO + CH_4$

proceeds with first order kinetics with respect to acetone with rate constant k s^{-1}. What is the conversion at the outlet of a cylindrical plug flow reactor with length L m and radius R m operating at steady-state? The feed rate of acetone is F mol/s. The inlet temperature and pressure are T K and P bar, respectively.

Ill-posed, Problem 3 can be framed and solved in several ways, all of which yield useful solutions depending on the conditions. If the tube is narrow in diameter and surrounded by a heat exchanger, solving Problem 3 with the information given, in isothermal operation, is reasonable. However, missing from the Problem 3 statement is that the reaction is fast and exothermic. The inclusion of thermal effects in the model is thus important under certain circumstances. Given the heat of reaction and the dependence of the rate constant on temperature, we can consider adiabatic operation as an extreme scenario. Or, we can surround the reactor by a heat exchanger with a coolant of fixed temperature. Then, we can treat the radial dependence of the heat distribution in the reactor and the changing temperature of the coolant in the heat exchanger. Finally, synthesizing the concepts learned in the class, students can quantitatively identify the conditions under which each solution holds by considering nondimensional numbers.

Notably, a student equipped with a recipe could make a set of assumptions– emphatically, without even realizing it– and solve Problem 3 with the information given. The act of solving Problem 3 in a variety of circumstances trains students to be appropriately inquisitive when encountering a reactor problem outside of the classroom and to frame problems themselves. As a result, somewhat serendipitously, students have learned chemical engineering design along the way.

Acknowledgments

Thanks to Jeff Reimer for inspiration on my teaching statement and Joaquin Resasco for discussions on teaching philosophy.