Fundamental Concepts and Computations in Chemical Engineering

by Vivek Utgikar

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Reviewed by

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The first contact with freshmen is a delicate balance with several influences pulling in various directions. First and foremost, we would like to impart the excitement we feel for the subject and why it is worthy of a lifetime of devotion and study. On the other hand, we must face the broad range of technical backgrounds inherent in chemical engineering relative to other engineering disciplines, especially as biomolecular applications play increasingly significant roles. The description of the curriculum needs to encompass the rationales for the coursework as well as the sequence of courses to take and the necessary prerequisites. Simultaneously, we must impart at least a few technical skills, mostly computational in nature, so our colleagues in upper-level courses have a solid foundation on which to build. Finally, all of this must be accomplished in a nurturing environment, recognizing that first-semester freshmen are as much post-high school students as they are neophyte college students. Not all high schools are the same, and some may not offer physics, or even calculus. Yet, every student is precious and needs to be carefully guided to their most promising source of fulfillment.

A multitude of approaches has developed to cope with this polycephalous problem. One approach is to put freshmen of all disciplines in a single course, perhaps with supplementary workshops or seminars that are discipline specific. Our experience at The University of Akron (UA) showed that only about 15% of students transferred between disciplines, however. Therefore, it is worth considering that the majority of students may benefit more from tailored introductory coursework, while maintaining the ability to transfer without penalty. Among the discipline-specific approaches, one may put more emphasis on the computational aspects while another puts more emphasis on the "culture" of chemical engineering. At UA, we have favored computations first, using textbooks like those of Larsen[1] and Liengme,[2] but we maintain an interest in the cultural aspects by alternating weeks of their coverage with material external to the textbook. On the other hand, Vivek Utgikar's new book, *Fundamental Concepts and Computations in Chemical Engineering*, favors the more cultural approach first, similar to the well-established text of Solen and Harb.[3,4] Another related text by Denn has been reviewed previously.[5]

The text of Utgikar begins with three chapters providing background about the petro-chemical industry and what chemical engineers do. Chapter 2 provides a distinctive outline of chemical products and where they go. This coverage is reminiscent of classic treatises on industrial chemistry[6,7] and it merits increased attention in the curriculum. Chapters 3 and 4 discuss the curricular subjects of chemical engineering and the subject material in the abstract. In general, I am not sure that rapid-fire abstract coverage like this permeates the freshman psyche very effectively. As for the subject-specific lists of equations in Chapter 4, I prefer a just-in-time approach in which equations are immediately reduced to application. While these are all important equations, I think it might be overwhelming for some freshmen to develop expertise in all of these. Personally, I focus on retention of just three key equations to represent the chemical engineering curriculum: heat exchanger size (with four heuristic heat transfer coefficients), distillation column size (using Raoult's law and the Fenske equation), and reactor size (using the CSTR model). Nevertheless, UA freshmen find mastery of just these three equations to be quite challenging. Chapter 5 covers fluid flow and begins to introduce computational problems in section 5.3, starting with Excel's Goal Seek tool to solve for the Fanning friction factor. This example is well laid out and systematically solved. The second example illustrates interpolation using a trendline applied to a graph of viscosity vs. temperature. The resulting graph is left in the default format with axes unlabeled, gridlines, and the title "Chart Title." I believe there is a typo in the description of the resulting equation. The examples continue with average velocity and shear force on the pipe wall. Chapter 6 covers material balances for the input and output streams of a distillation column and for a reacting system with inerts and an excess component. This latter problem is especially important and related to CSTR sizing. It is solved first by stoichiometric methods then using matrix methods. This is a useful demonstration but an opportunity is missed to solve entire flowsheets with recycle using Excel's iteration feature. Chapter 7 covers energy balances, beginning with an example computing the adiabatic flame temperature. Heat exchanger sizing is also covered, where the overall heat transfer coefficient is given and the focus is on applying the log mean temperature difference. Chapter 8 covers thermodynamics and includes a fair amount of theory, including reaction and phase equilibrium (and the dreaded "fugacity"). The computational examples focus on applying the ideal gas law and solving for diffusion equilibrium in a membrane system. I expected a bubble, dew, and flash equilibrium problem. The book concludes with Chapter 9 covering kinetics. A trendline is applied to infer rate constants. There is no discussion of multiple linear regression or overfitting and the interpretation of the standard error estimates in the coefficients. Each chapter includes exactly 10 homework problems and every example includes solutions using both Excel and Mathcad. The homework problems are generally a stretch beyond the examples in the chapter. In Chapter 8 for example, homework is given applying the Peng-Robinson equation of state when only the ideal gas law is illustrated in the chapter. Osmotic pressure appears in a homework problem but is not mentioned elsewhere in the chapter.

I may be guilty of inertial thinking, but I am not strongly motivated to change direction based on this review. Both Liengme and Larsen provide texts that systematically build functional skill sets from a low level, like naming variables, to VLOOKUP, to a visual basic introduction. Liengme's text does a slightly better job of building skills in the chapter that are then reinforced in the homework. Larsen's text has the advantage of fewer typos. The subject-specific topics, like Antoine's equation, equations of state, or matrix mass balances, are brought up in the context of a particular computational skill. Very little of either textbook is devoted to discussion of equations and models in the abstract. This pattern of building computational skills is inherently logical but it leaves more responsibility to the instructor to elaborate on the significance and context of a subject specific topic. I find this approach more amenable to nurturing freshmen. The focus on Excel in these two texts is a limitation if MatLab or Mathcad skills are desired, but I believe it is more efficient and less confusing to pick a single computational tool and select a textbook accordingly. If authors wanted to release distinct versions of their texts for each computational platform, that would be preferable in my opinion.

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