ChE Curriculum of the Future: Re-evaluating the Process Control Course

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I recently attended a department chairs workshop in Orlando, FL ("New Frontiers in Chemical Engineering Education", 1/27-29/03), where a group of about 45 faculty wrestled with how to make the Ch.E. curriculum more relevant for today's graduates. One of the major undercurrents of this workshop (which will have follow-on workshops later this year) was to determine what role biological science and engineering will play in the future curriculum. A corollary to this question was if new courses are added to the curriculum, what can be removed? Clearly all departments face a variety of local constraints that result in relatively inflexible paths to the degree (with a hard constraint on the total number of credit hours… a zero-sum game).

After the first breakout sessions, different groups reported a long and varied list of proposed changes to the curriculum. Notably, a few groups reported that the subject of process control was high on the "hit list". While process control was not perceived as the only option, I was not expecting to see it in such an egregious position. This caused me to begin thinking about why the value of process control to academic chemical engineers is apparently not as high as I thought it was. Of course, my views are strongly influenced by the fact that I have spent 35 years teaching , writing textbooks, and doing research in this field.

I inquired of my colleagues at the workshop why process control had reached such a "lowly state" in their eyes, and I began to get a few clues as to why this may be the case. With the emphasis today on "bio, nano, enviro, and info" at funding agencies such as NSF, NIH, and DOD, it is not clear where process control researchers fit into this agenda. Hiring faculty at research-oriented departments has certainly moved in the same direction as the available funding (which includes the disproportionate effect of the Whitaker Foundation in the bio area). Faculty in these areas are oriented towards discovery-type research, far from the details of making commercial quantities of products.

A related article ("Refocusing Chemical Engineering") was published in the January, 2002 issue of Chemical Engineering Progress, Ed Cussler et al. declared that a number of fields like thermodynamics, reaction engineering, transport, and control can be relegated to the scrap heap of "mature technologies" that will not have much future impact in the gain in knowledge. Ed et al. proposed dropping courses on control and optimization at the end of the article but add several disclaimers: "First, we accept without question the importance of process optimization to commodity chemicals. Secondly, we recognize that process control has a key role in ensuring the success of those other cornerstones of competitive advantage in specialty product manufacture; safety, consistency and quality. Our third hesitation stems from our unwillingness to sacrifice any of our technical core to less-quantitative business ideas. Still, we recognize that a large part of our future is going to be in areas where different skills are needed". So, Ed, what discipline will staff chemical manufacturing in the future, mechanical engineers? The semiconductor industry already discovered that chemical engineers are the best process engineers ("process" interpreted very broadly). Or is manufacturing as we know it not going to exist in 2020? See www.cchrq.org/vision/index.html for one perspective on how it will change (Vision 2020).

A third strike against academic process control as an important technological contributor was the recent article published by long time practitioner Greg Shinskey (retired from Foxboro) in IEC Research, Vol. 41(16) p. 3745 (2002). Greg states there has been little or no progress in 35 years in closing the industrial-academic gap in process control, causing B.S. graduates to be unprepared for industrial assignments. This is reminiscent of statements I heard at technical meetings 30 years ago that "control research is dead". Obviously it rose from the ashes in the 1970s and has been alive and well for the past 20 years. Of course Greg Shinskey also believes that any useful analysis can be done on the back of an envelope, which suggests that academics in many fields of chemical engineering are not engaged in meaningful work. It is interesting that Shinskey and Cussler express opposing views. Shinskey argues that nothing important has been accomplished, whereas Cussler states that so much has been accomplished there are no major improvements expected in the future. To use an analogy articulated by an industrial colleague, Shinskey says we have been driving in the wrong direction (but we can turn the car around), while Cussler says the car is out of gas and drivers are no longer needed.

Industrial chemical engineers seem to have little doubt that process control is important to keeping modern chemical plants operating, a view that was articulated by several industrial attendees at the Frontiers workshop. So maybe the disconnect is how the typical faculty member views where employment opportunities will reside in the future, say in 2020. If chemical engineers are not involved in making value-added "stuff" at a desired quality level, the contribution of chemical engineering to the national economy will undoubtedly be greatly reduced. What do we expect B.S. chemical engineers to be doing then?

Other observations that emerged at the workshop were that a systems viewpoint is very important for chemical engineers and separates them from chemists, biologists, and other engineers. It was pointed out that unsteady-state behavior and feedback control are important concepts in living systems, and any organism that is at steady-state is dead (arguing for an understanding of dynamic process models). Also chemical engineers have to deal with a wide range of scales, from molecular to macro, even enterprise levels, which suggests that mathematical models are important. So that seems to bode (no pun intended) well for keeping process control in the curriculum. However, another view that emerged at the workshop was that we could insert a little bit of process control in five or six courses. Realistically, that approach may not be effective and could be easily diminished in any course by individual faculty option.

So why does the process control course cause fear and loathing among our non-control colleagues? First, like design, it is usually taught by a small subset of faculty in a typical department (as opposed to other core courses in thermo, transport, unit operations, etc.). It perhaps is one of the "short straws" in teaching assignments. Second, process control is perceived by many faculty to be an applied mathematics course that heavily focuses on Laplace transforms, analytical solutions to linear differential equations, linear algebra, frequency response, optimization, and the like, without much practical content beyond tuning a PID controller. Computer simulation takes a back seat to theoretical analysis. This is the way many faculty taught undergraduate process control 20 or more years ago, but some departments may not have changed the emphasis or content of the course. In fact the availability (since 1998) of computer-based tools such as Simulink in MATLAB or Control Station (by Doug Cooper) has completely changed the way in which process control can be taught.

The topics I cover when I teach process control include dynamic behavior (with about one lecture on Laplace transforms and analytical solutions to ODEs), physical and empirical modeling, computer simulation, measurement and control hardware technology, basic feedback and feedforward control concepts, and advanced control strategies. Many of these topics can be presented to reflect applications in biochemical or materials engineering. More emphasis could be placed on modeling, optimization, and data analysis/statistics in a revised course. Unfortunately existing textbooks (including mine) mostly use examples from continuous processes in petrochemical plants (vs. batch specialty products). This shortcoming can be addressed near-term by using the world wide web to disseminate new course materials that augment existing books. A new committee organized under the CACHE Corporation and led by CACHE trustees Frank Doyle, Sangtae Kim, and Tunde Ogunnaike is focusing on developing biosystems course materials in the areas of design, control, kinetics, and separations. There already is a good start for such a website in the Teaching Resource Center at www.cache.org. One outcome of the Frontiers workshops being held in 2003 will likely be a proposal to NSF to fund the development of educational modules to supplement existing textbooks in all core areas.

Most educators agree that a systems viewpoint is valuable for chemical engineering graduates. Dynamics, feedback, and stability are intellectual underpinnings required for understanding many new and complex systems of interest to chemical engineers. Control, like design, can be taught in a way so that students must integrate knowledge from other core ChE courses in process modeling and analysis of process behavior. There are not many courses in the curriculum that fulfill these needs. Constructive change is critical to the health of our profession, so I invite all faculty, especially those from the computing and systems community, to join this discussion to revitalize our curriculum.

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