Paper ID #19447

The state of the chemical engineering curriculum: Report from the 2016 survey

Dr. Margot A Vigeant, Bucknell University

Margot Vigeant is a professor of chemical engineering at Bucknell University. She earned her B.S. in chemical engineering from Cornell University, and her M.S. and Ph.D., also in chemical engineering, from the University of Virginia. Her primary research focus is on engineering pedagogy at the undergraduate level. She is particularly interested in the teaching and learning of concepts related to thermodynamics. She is also interested in active, collaborative, and problem-based learning, and in the ways hands-on activities such as making, technology, and games can be used to improve student engagement.

Dr. Kevin D. Dahm, Rowan University

Kevin Dahm is a Professor of Chemical Engineering at Rowan University. He earned his BS from Worcester Polytechnic Institute (92) and his PhD from Massachusetts Institute of Technology (98). He has published two books, ”Fundamentals of Chemical Engineering Thermodynamics” and ”Interpreting Diffuse Reflectance and Transmittance.” He has also published papers on effective use of simulation in engineering, teaching design and engineering economics, and assessment of student learning.

Dr. David L. Silverstein P.E., University of Kentucky

David L. Silverstein is a Professor of Chemical Engineering at the University of Kentucky. He is also the Director of the College of Engineering’s Extended Campus Programs in Paducah, Kentucky, where he has taught for 18 years. His PhD and MS studies in ChE were completed at Vanderbilt University, and his BSChE at the University of Alabama. Silverstein’s research interests include conceptual learning tools and training, and he has particular interests in faculty development. He is the recipient of several ASEE awards, including the Fahein award for young faculty teaching and educational scholarship, the Corcoran award for best article in the journal Chemical Engineering Education (twice), and the Martin award for best paper in the ChE Division at the ASEE Annual Meeting.

The state of the chemical engineering curriculum: Report from the 2016 survey

The AIChE Education Division Survey Committee annually asks chemical engineering department faculty about course offerings in core topics in chemical engineering; recent surveys include controls (2015), the transport sequence (2014), and elective courses (2013). The most recent survey took a step back from the individual topics to consider the curriculum as a whole. Prior to ABET 2000, accreditation criteria cultivated a high level of similarity in chemical engineering curricula. Now that two whole accreditation cycles have passed under the much less prescriptive criteria, how has the curriculum changed overall? Survey questions addressed not only the degree of change but the process for change and the internal and external drivers for those changes. Responses indicate that change overall is most commonly incremental, although some departments have engaged in a wholesale revision of their curriculum.

Introduction

The AIChE Education Division Survey Committee seeks yearly to capture the state of the art in undergraduate instruction in chemical engineering.

While there are older studies of the curriculum Barker, Dee, "Undergraduate Curricula 1976", *Chem Eng. Ed*., Vol 9(2), pp.60-63,96., pre- 2000 ABET accreditation criteria tended to foster a high level of similarity in chemical engineering curricula. Table 1 shows the 1996 chemical engineering program criteria as cited in [1].

Table 1: 1996 Chemical Engineering Program Criteria

(A-1)"working knowledge, including safety and environmental aspects, of:
(A-2) material and energy balances applied to chemical processes
(A-3) thermodynamics of physical and chemical equilibria
(A-4) heat, mass, and momentum transfer
(A-5) chemical reaction engineering
(A-6) continuous and stage-wise separation operations
(A-7) process dynamics and control
(A-8) process design "

Readers with undergraduate degrees prior to 2000 may recognize Table 1 as a list of their core courses. In 2000, ABET adopted a completely revamped accreditation criteria for engineering programs, which were referred to at the time as "EC2000".The change constituted a shift from counting input credits to focusing on the definition of student outcomes and development of strategies for assessing whether students were achieving these outcomes. These new and less prescriptive assessment criteria meant that there was a potential for programs to become more divergent in their approach to the curriculum, though they remain bounded by program-specific criteria.

> The curriculum must provide a thorough grounding in the basic sciences including chemistry, physics, and/or biology, with some content at an advanced level, as appropriate to the objectives of the program. The curriculum must include the engineering application of these basic sciences to the design, analysis, and control of chemical, physical, and/or biological processes, including the hazards associated with these processes. (ABET Engineering Accreditation Committee Program Criterion for Chemical Biochemical, Biomolecular, and Similarly Named Programs[2].

Now that more than two full six-year accreditation cycles have passed since the adoption of EC2000, it seemed an appropriate time to take a snapshot of the chemical engineering curriculum and the extent to which it has shifted.

Methods

The survey was constructed by the authors in consultation with other interested parties. A team at NJIT undertook a concurrent effort to build a database of required chemical engineering coursework based on published course catalogs, so it was decided this work would not replicate that effort but would refer to it [3]. The survey consists of 31 questions on the topics of: departmental characteristics, curriculum design and redesign, decision making, and concentrations, minors, and distinguishing programs. When chairs were asked to compare the current state to a previous state (for example, number of chemistry courses required), the reference time point was 1990 or the founding of the department, whichever was more recent. Survey text is attached as Appendix A. A link to the survey was sent to the department chairs/heads of all ABET accredited programs through the list maintained by the AIChE Education Division. The survey completion request was initially sent on August 19, 2016 and then followed by several reminder requests. The survey received 55 substantially complete replies for a 35% participation rate.
Quantitative results are presented as pie charts so the distribution of responses is clear. Text results were read for emergent themes are used to give nuance or specific examples for the quantitative results.

Results and Discussion

58 surveys were started, 55 of which were completed. All responses were from US institutions, 78% of which were public state institutions. Chemical Engineering faculty size at the responding schools ranged from 4 to 34, with graduating class sizes from the 1-20 range to the 161-180 range. All responding institutions claimed a growth in graduating class size relative to five years ago, 55% saying class size had doubled or more.

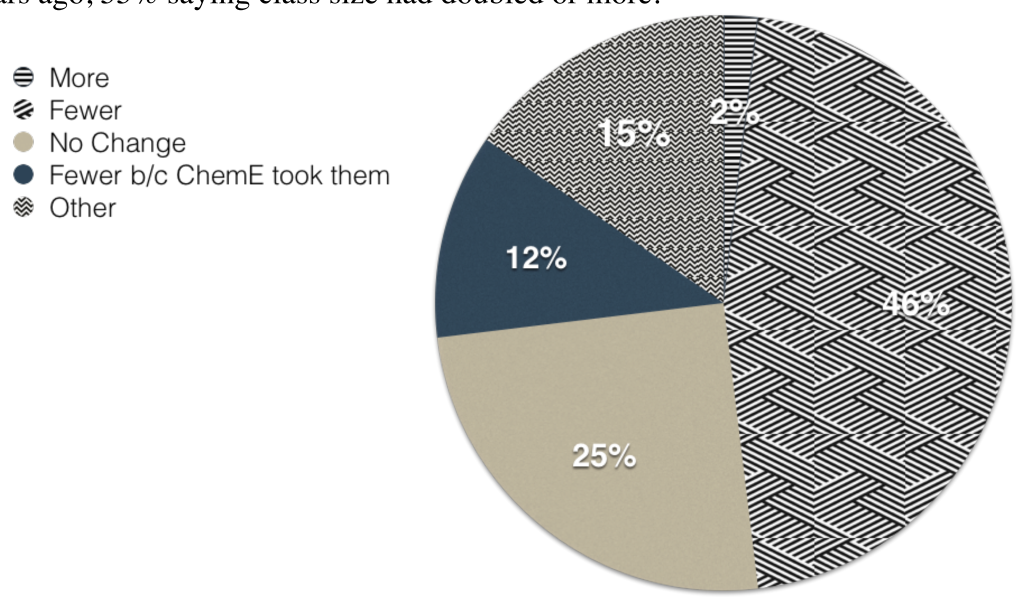

Figure 1: Change in Required Chemistry Credits relative to 1990/ department founding

Figure one shows the distribution of changes to required courses in chemistry between 1990 and 2016. Only one quarter of departments have the same number of required credits, with the largest segment of all reporting departments having fewer chemistry credits now than they did in the past. Going further into these data, the most common change is replacing all or some of the previously required physical chemistry courses with additional coursework in chemical engineering thermodynamics or another in-department offering. 67% of departments do still require at least one course in physical chemistry.

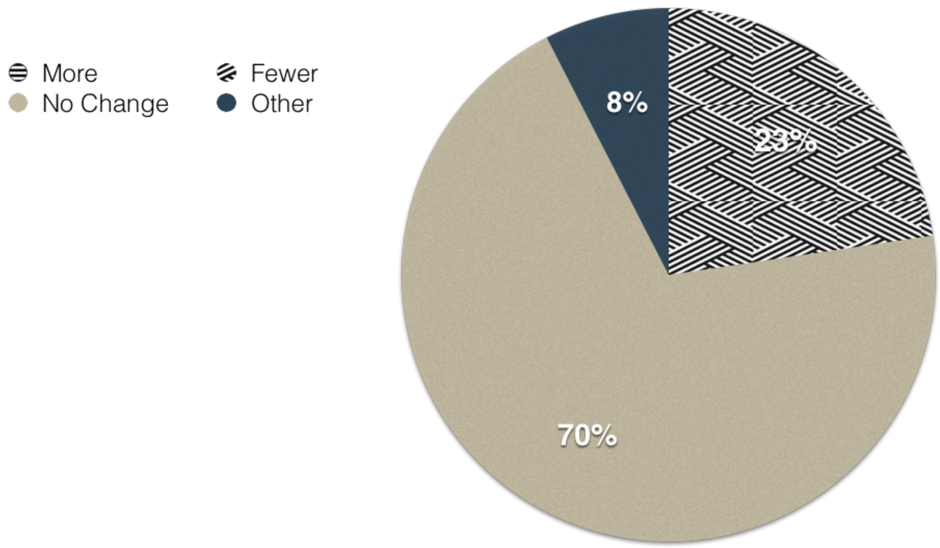

Figure 2: Change in Physics credits relative to 1990 / department founding

As seen in Figure 2, offerings in physics have been more stable than for those in chemistry, perhaps because chemical engineers have historically taken far fewer credits in physics and so there is less to drop. 78% of programs require two semesters or quarters of physics, 11% require only one, and the remainder have additional or flexible coursework requirements, such as 3-6 credits of additional upper level work in either chemistry or physics.

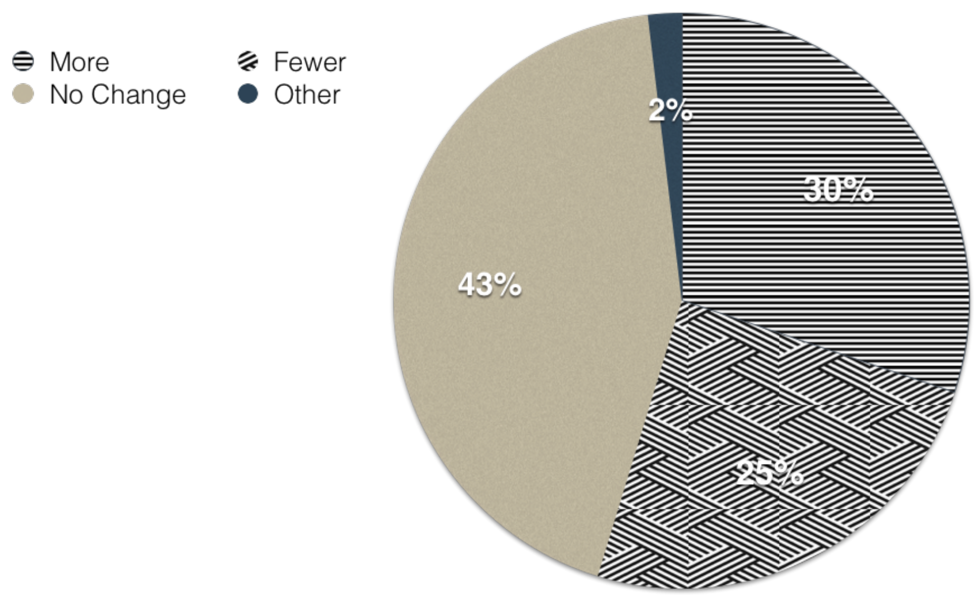

Figure 3: Change in Chemical Engineering core credits relative to 1990 / department founding

The chemical engineering core seems to be relatively stable in total credits, with nearly equal numbers of departments reporting expansion and contraction of their required credits and 43% of departments reporting no change. While the numbers of required courses seem not to have changed extensively, many departments noted that the content and exact courses have evolved since 1990. For example, one department reported dropping one required course in favor of adding a required course in process safety. When course titles remain the same, there are often still significant content and outcome changes relative to 1990, such as incorporation of modern simulation tools, biological or biomolecular content, or incorporation of teamwork and other professional skills.

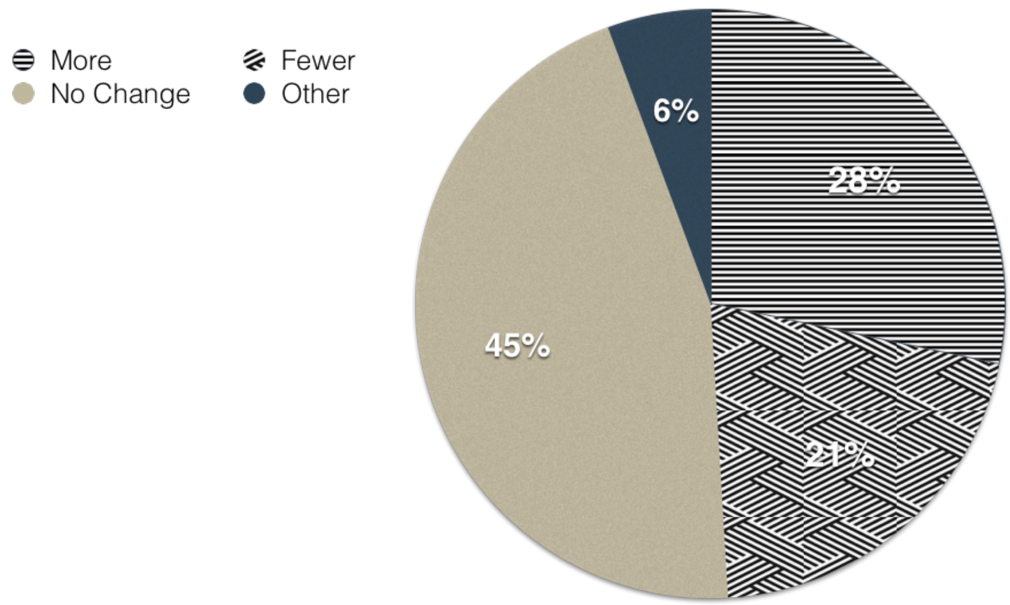

Figure 4: Change in technical elective credits relative to 1990 / department founding

As with the Chemical Engineering core, technical elective credits have had similar numbers of departments increase, decrease, and leave unchanged the number of courses, as seen in Figure 4. As seen in the Electives survey [4], technical electives vary widely in content and content area from institution to institution and are often test sites for the entry of new content into the core curriculum.

Two "big picture" questions attempted to capture how often the curriculum as a whole is considered for revision and the extent to which this has occurred. These questions are summarized in Figures 5 and 6.

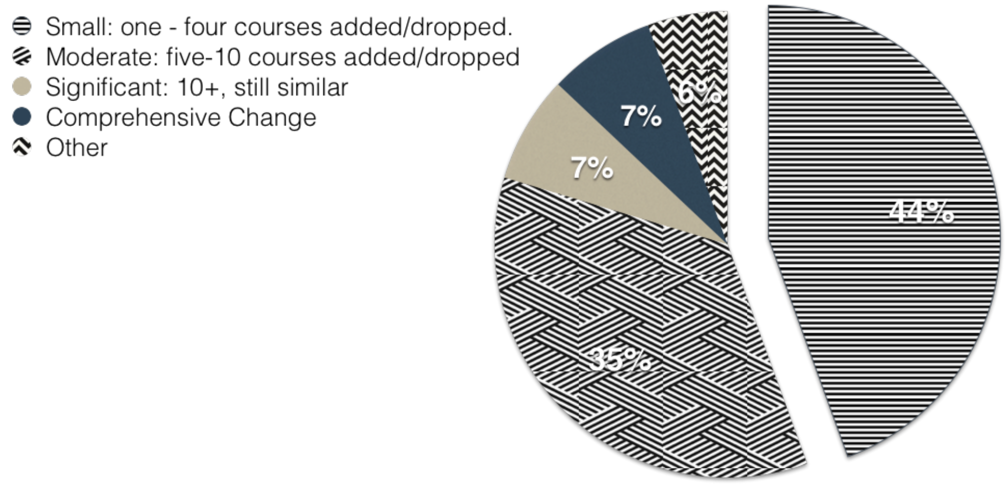

Figure 5: Extent of curricular change from 1990 / department founding

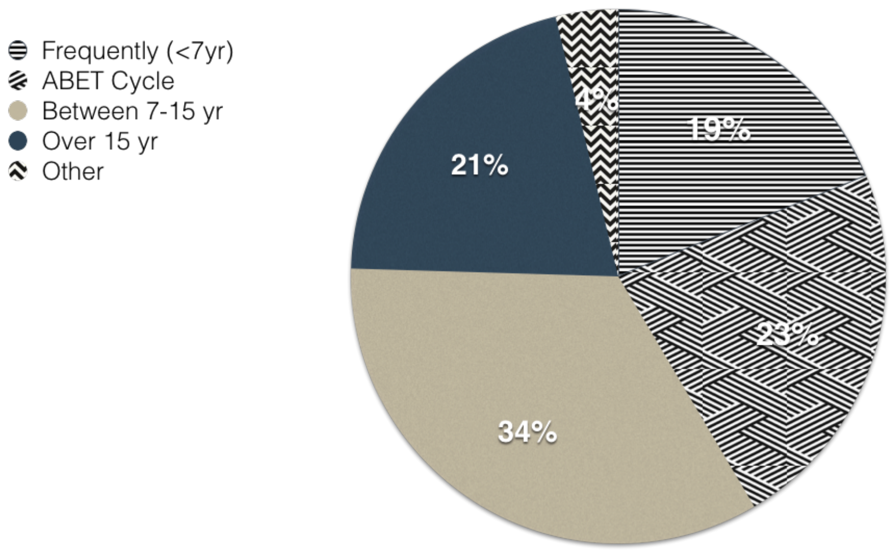

Figure 6: Frequency of curricular revision

One department described their frequency of revision as consisting of near continuous small-scale modifications as part of continuous improvement and more rare large scale changes as data warrant. Looking at Figures 5 and 6, this statement could describe many additional departments as well. The plurality of curricula are substantially similar to those offered by their departments 25 years ago.

As was described in the text for Figure 3, the apparent stability implied by Figure 5 may hide numerous modifications within courses that do not change the name or core content of the courses. Since 1990, resources for instructors and students to enhance instruction beyond the printed book and weekly problem set has become much more widely available. Resources such as LearnChemE [5] and the AIChE Concept Warehouse [6] compliment and expand possibilities for classroom instruction without changing the core concepts or titles of the courses. That being said, 7% of programs have undergone comprehensive revision since 1990. For example, in 2004 the University of Pittsburgh started implementing their Pillars of Chemical Engineering course sequence, a significant reorganization the way in which core concepts have been traditionally broken up into courses [7].

Chairs were also asked to comment on the process for curricular change. Most curricular change was subject to review not only by the department chair and faculty, but to a college or institutional committee, and often a dean or associate dean. Only three of 55 departments indicated that changes were exclusively under the control of the department members. By contrast, 32% of all departments have experienced an externally mandated credit change since 1990; most commonly, this is a reduction in the number of credits required to graduate, specified by trustees or a similar oversight body.

Finally, chairs were asked to share information about minors, concentrations, or other similar curricular customizations and designations that they make available to undergraduate students. 62% of departments reported having such designations available. Broadly, these can be described as in-department offerings aimed at chemical engineering majors and out-of-department offerings that are options for chemical engineering majors. The most common responses for in-department offerings were concentrations in bio-related topics (bioengineering, pharmaceutical, biomed), energy-related, polymers, pre-med, and materials, and the most common mechanism cited for this was student choice of tech electives. Of the 32 programs that offer this type of customization, these break nearly evenly into those who noted that this was a popular thing for students to pursue, those who noted that very few students pursued available concentrations, and those who made no comment on student numbers. This is interesting because it is not obvious from the descriptions of program requirements or content area why popularity should be so variable. For broader offerings, minors and concentrations in entrepreneurship, business, and science or computing minors were mentioned. The first two were noted for being relatively new and popular by several respondents.

Taken as a whole, students from 1990 would find much that they recognize in the chemical engineering curricula of today, while they might not recognize the classroom activities or co-curricular opportunities as familiar.. In discussion of these results at the AIChE 2016 Annual Meeting, it was observed that a stable curriculum is a sign of a stable body of knowledge and a mature field, rather than a sign of stagnation.

Works Cited

1. Pintar, A., B. Aller, T. Rogers, K. Schulz, and D. Shonnard. “Developing an Assessment Plan to Meet Abet Ec2000.” Paper presented at the American Association for Engineering Education, Charlotte, NC, 1999.
2. ABET. 2017. Criteria for Accrediting Engineering Programs, 2017-2018. http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2017-2018/ (accessed February 12, 2017,
3. Voronov, R., S. Basuray, G. Obuskovic, L. Simon, R. B. Barat, and E. Bilgili. “Statistical Analysis of Undergraduate Che Curricula of U.s. Universities.” Paper presented at the American Institute of Chemical Engineers National Conference, San Francisco, 2016.
4. Vigeant, Margot, and David Silverstein. “Results From the Aiche Education Annual

Survey: Chemical Engineering Electives." Paper presented at the American Society for Engineering Education, Indianapolis, IN, 2014.

5. Falconer, John, L., J. L. de Grazia, G. Nicodemus, K. McDanel, and M. Medlin. "Teaching/learning Resources for Chemical Engineering: Www.learncheme.com." Paper presented at the American Society for Engineering Education, Seattle, WA, 2015.
6. Koretsky, M., Falconer, John, L., Brooks, B. J., Gilbuena, D., Silverstein, D., Smith, C., and Miletic, M. "The AIChE concept warehouse: A tool to promote conceptual learning." *Advances in engineering education* 4, no. 1 (2014): 1-27.
7. Mccarthy, J., A. A. Abatan, R. S. Parker, and Mary Besterfield-Sacre. "Work in Progress: Pillars of Chemical Engineering." Paper presented at the Frontiers in Education, Indianapolis, IN, 2005.