

## Results from the AIChE Education Annual Survey: Chemical Engineering Electives

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David L. Silverstein is the PJC Engineering 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 14 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 Cororan 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.

## **Abstract**

The AIChE Education Division survey committee continues the tradition of an annual national survey to better understand the current state of a particular aspect of the chemical engineering curriculum. In 2013, the committee asked departments about chemical engineering electives. This paper summarizes the results from the multiple choice survey as well as from selected answers to a long-form follow up survey sent to volunteer departments.

We defined “chemical engineering electives” as courses offered by the chemical engineering department or faculty that may be taken by undergraduate students but are not specifically required in order to graduate. The word that best fits chemical engineering electives is “diverse”. It might be argued that the most clear differentiator among chemical engineering undergraduate programs is the areas highlighted by their elective offerings. Nearly 100 different elective course topics were reported by the 96 programs responding to the survey. The most popular topical offerings are Polymer Science, Bioprocess Engineering, Nanomaterials, and Advanced Transport. Typically, undergraduates are expected to take 2-3 chemical elective courses, although the range spans from zero to 6. It should be noted that the programs requiring zero chemical engineering electives usually require instead “technical”, “engineering”, or “science” electives in similar quantity to the chemical engineering electives offered by other departments. In addition to the numerical summary results, this paper will also report on department chairs’ responses to the administrative question of how topics are selected, integrated, or let go from year to year.

## **Introduction and Background**

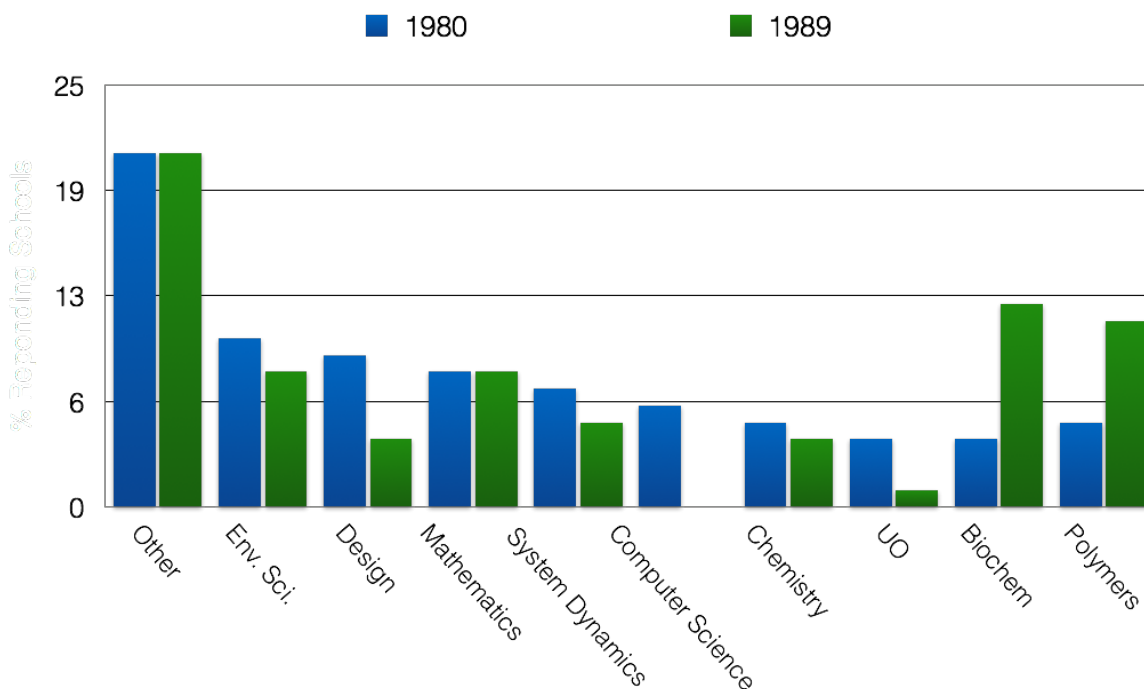
The AIChE survey carries on the tradition of discipline-wide curricular surveys established over 30 years ago. These surveys provide useful norming information to departments on the state of the curriculum throughout the United States and in participating international programs. Recent surveys have assessed first-year courses, mass and energy balances, chemical reactor design, and capstone design (Silverstein et al.; Silverstein and Vigeant; Silverstein). Surveys are conducted online, and responses are solicited through the Chemical Engineering Chair listserv.

This year’s survey was on Chemical Engineering Electives. Of necessity, this considers course titles and undergraduate curricular requirements more so than an in-depth consideration of textbook, specific content coverage, or approach as with the other surveys.

In the survey, Chairs were presented with a list five common over-arching elective areas: Bio-Related; Materials-Related; Advanced Core; Sustainability; and Process-Type, each hosting 5-10 typical course titles. The “typical” course titles were

generated from an informal survey of representatives of five different institutions, taken at the previous year’s ASEE meeting. Chairs were asked to check which ones were offered by their department on a regular basis. While the survey asked both for courses offered every year and those offered periodically, in the plots that follow both schedules are combined as “offered regularly”. Options for free-response in an “Other” category were also offered. Of the departments surveyed, 76 responded, generating 72 complete responses, representing 71 institutions in the United States and one in Indonesia.

We had access to three previous elective surveys, conducted in 1980, 1985, and 1989 (Eisen; Eisen; Eisen). Figure 1 summarizes the results of the earlier surveys (note 1985 comments on emerging technologies and does not provide data of the type in 1980 and 1989).



**Figure 1: Historical data (% of responding schools)**

While comparison of the data in Figure 1 with the data that follow suggests that electives are much more diverse now than in the past, but it may also reflect the greater variety of questions and analysis that can be done with an online multiple choice survey relative to the paper-based survey used in the 1980’s.

## Results

### *Demographics*

We asked chairs to characterize the size of their departments as well as the number of electives typically offered, as shown in figures 2, 3 and 4 below.

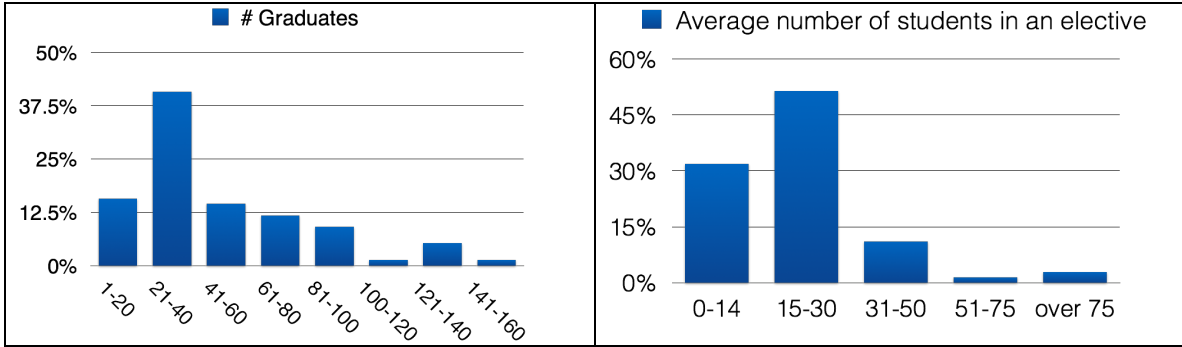


Figure 2: Graduating class size (left) and Typical Elective class size (right). (% of responding schools).

Unsurprisingly, elective enrollment is typically ½ or less of the overall graduating class size.

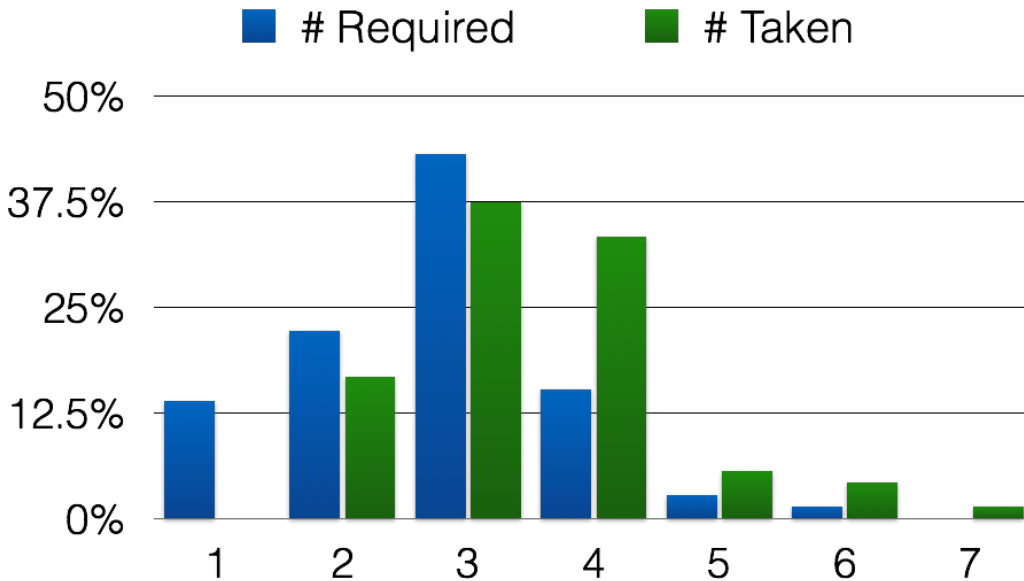


Figure 3: Number of required elective courses (% of responding schools)

While most programs require two or three elective courses, students tend to take at least one more than is required.

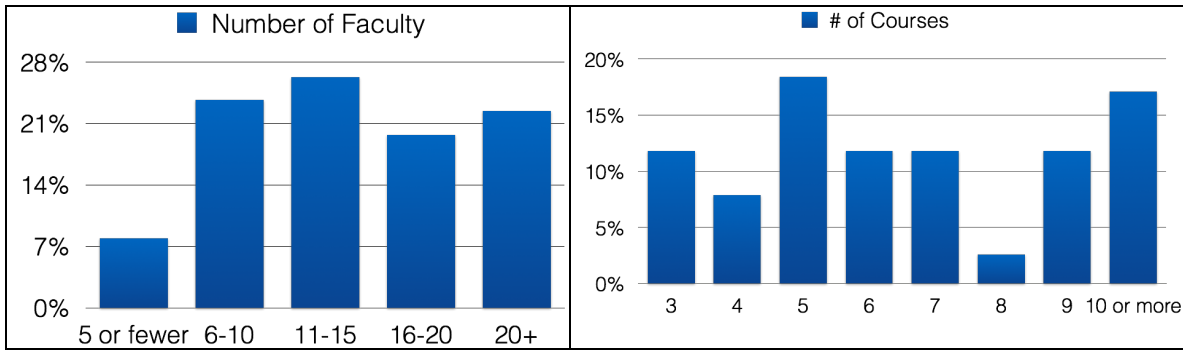


Figure 4: Number of faculty (left) and Number of elective courses offered during an academic year (right). (% of schools responding).

The authors were curious if the elective offerings would be more clearly associated with the number of students in the program, the interest areas of students in the program, or the number and interest of faculty in the program. Based upon a comparison of figures four and two, it appears electives are more closely associated with faculty than with students.

Elective Offerings

Elective courses were grouped into five topic areas plus “other”. The most common electives are offered at 50% or more of responding programs, and there is no topic area that is universally offered.

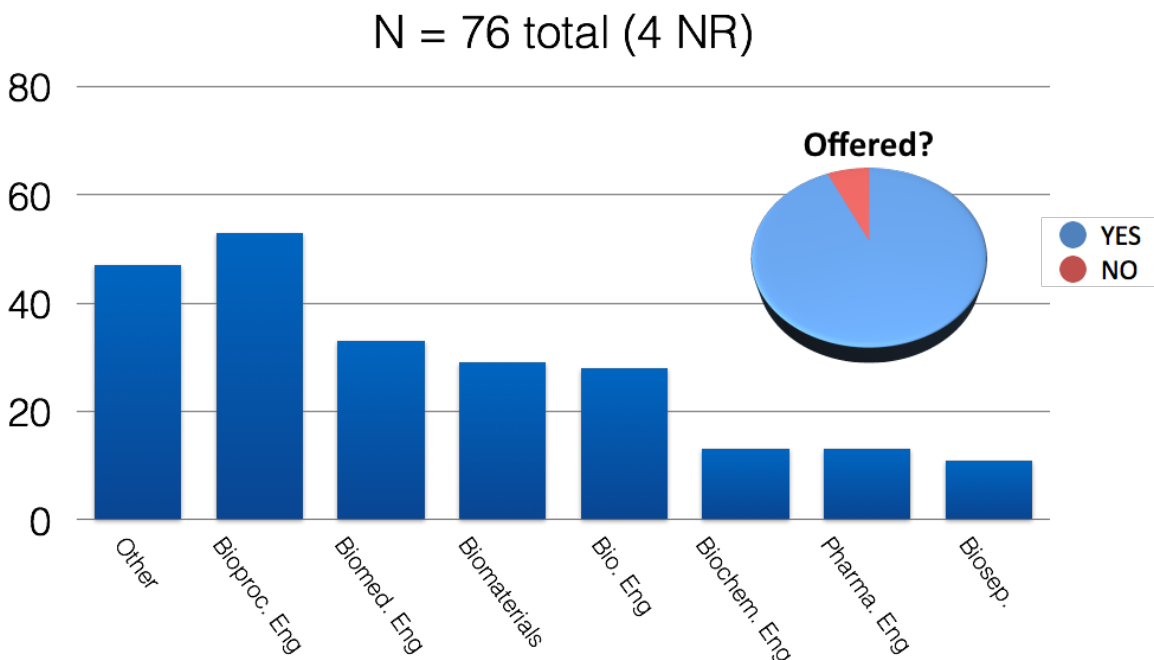
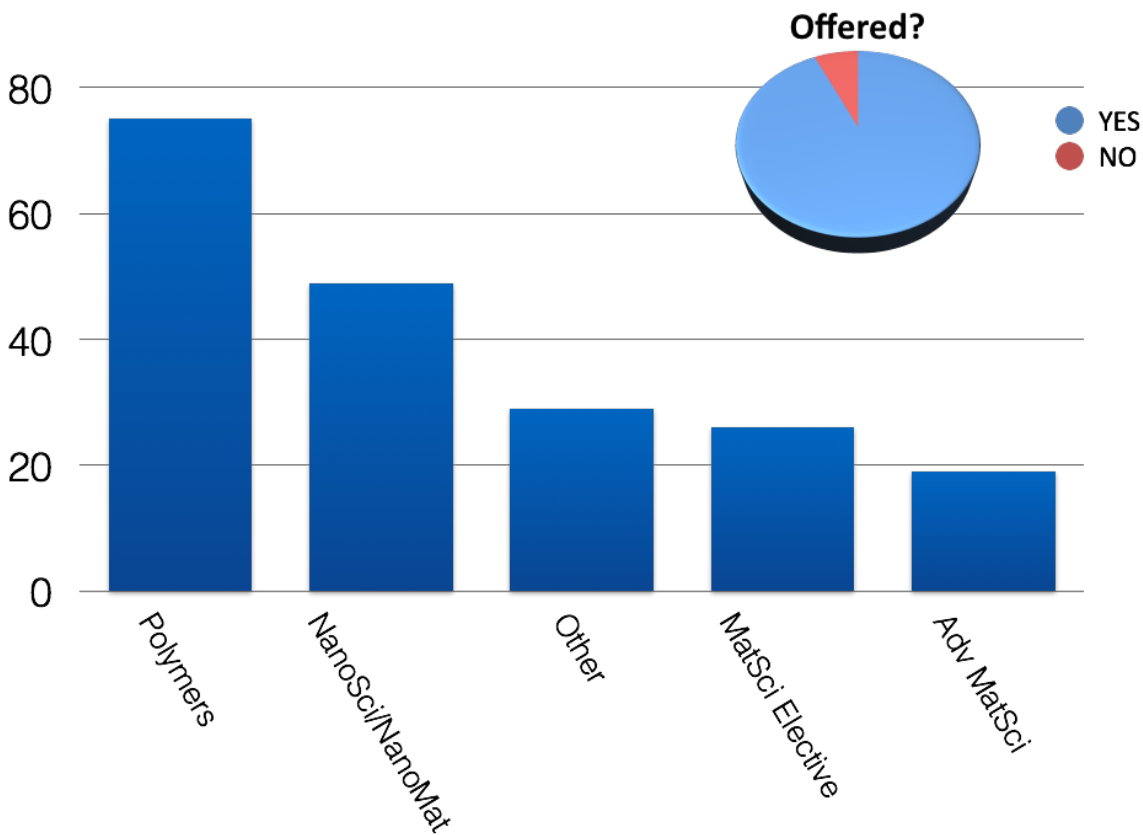


Figure 5: "Bio-Type" electives (% of schools responding); inset is fraction of schools indicating they offered courses in this area.

In the early 2000's, a number of schools added "Bio-" to their department titles or created separate programs or tracks for a biological focus. This is reflected by the commonality of these types of electives, as shown in figure 5. For an indication of the courses included in the "other" category, please see figure 10.



**Figure 6: "Materials-Type" electives (% of schools responding); inset is fraction of schools indicating they offered courses in this area.**

As shown in figure 1, Polymers was an emerging elective area in the 80's. It continues to be the most widely offered elective in the materials area, although "nano-" type electives are catching up. It should be noted that some programs require a course in materials science, meaning that their offerings are not included in the "MatSci Elective" bar.

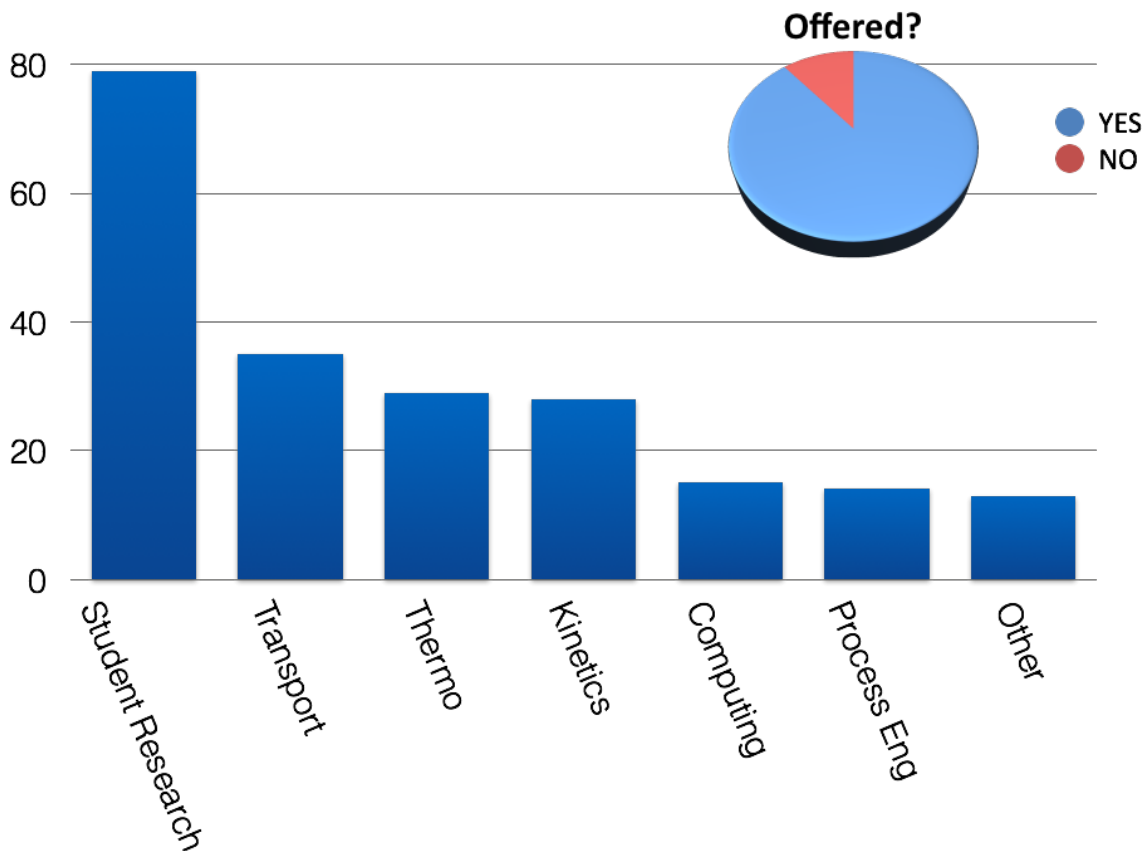
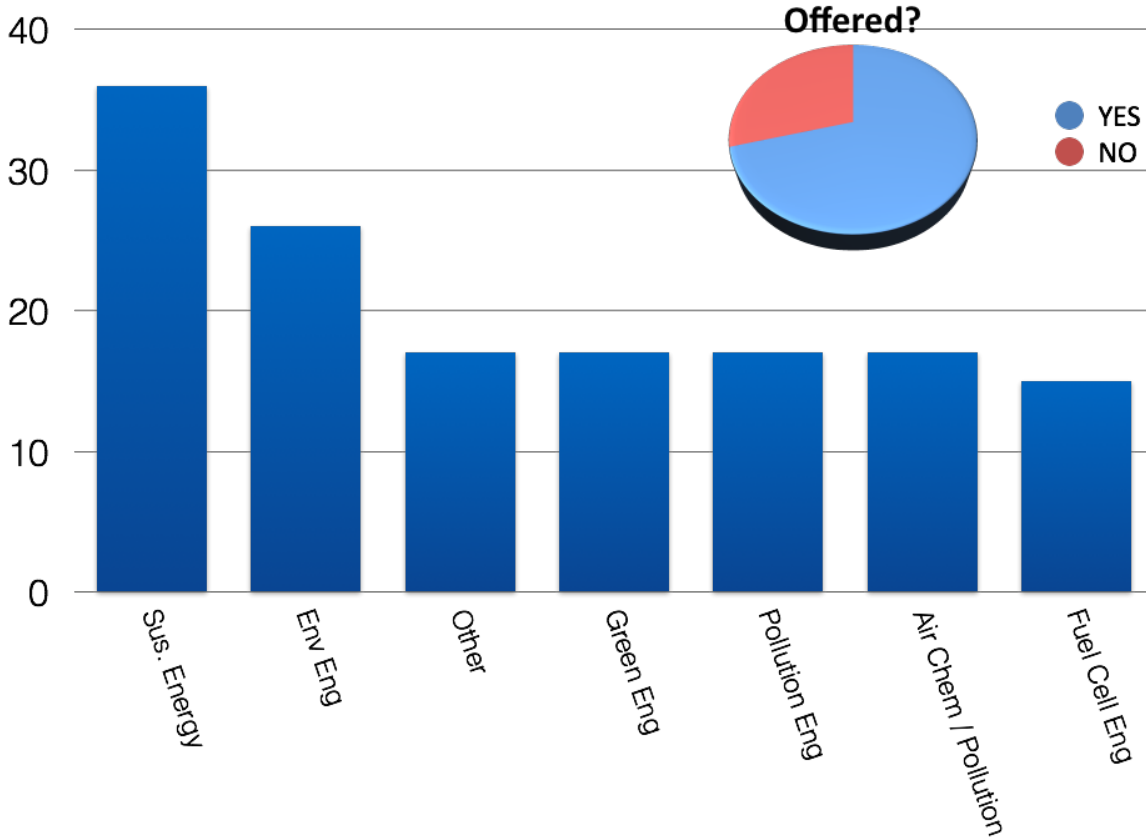


Figure 7: "Advanced-Core" electives (% of schools responding); Note that all y-axis labels should be understood to have the word "Advanced" in their title. Inset is fraction of schools indicating they offered courses in this area.

Advanced core courses are typically graduate-level courses that may be open to qualified undergraduates. Our data do not distinguish this from undergraduate-only offerings. The single most common elective in our survey is undergraduate research for course credit, although it is somewhat surprising this is not an option at slightly more than 20% of programs.



**Figure 8: "Sustainability-Type" electives (% of schools responding); inset is fraction of schools indicating they offered courses in this area.**

For figures 8 and 9, the y-axis shifts to a maximum of 40% (down from 80% in figures 5-7), indicating that the Sustainability and Process electives are somewhat less common than Bio-, Materials- or Advanced electives. Electives devoted to sustainability may be masked by the incorporation of sustainable practices (waste heat recovery, recycle, pollution control, etc) into required core courses such as capstone design.



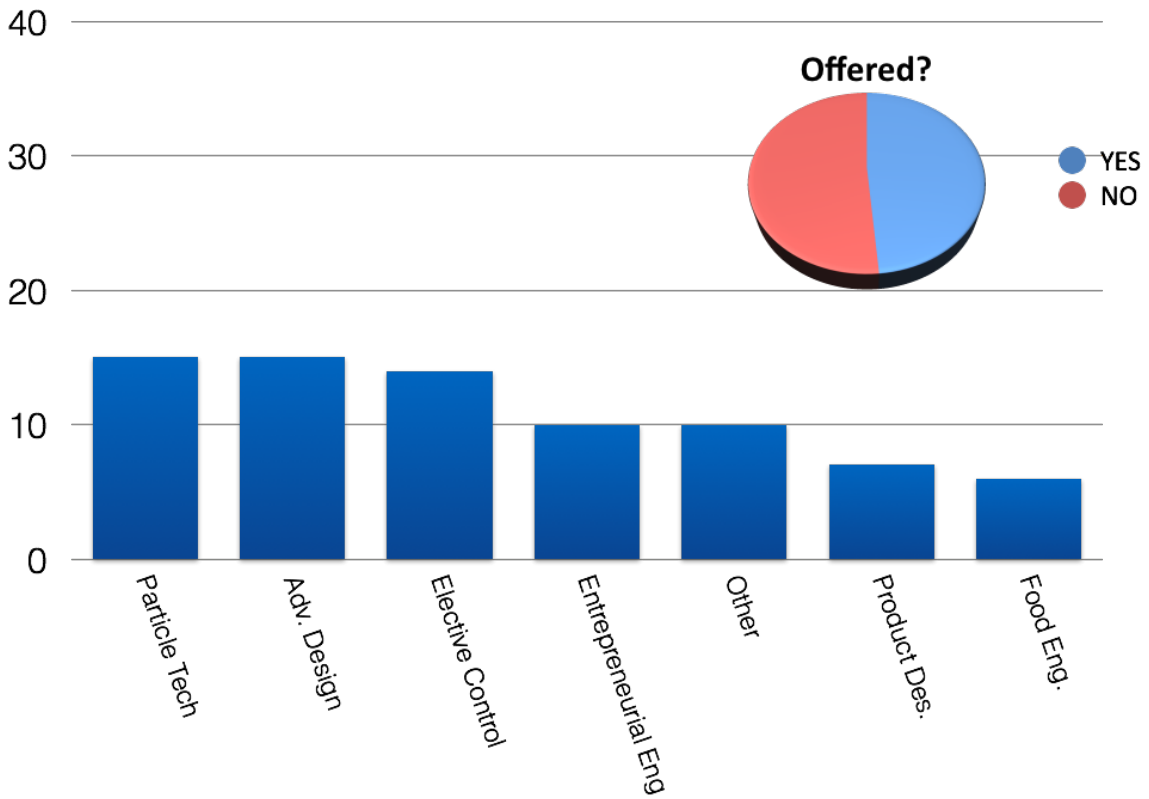


Figure 9: "Process-Type" electives (% of schools responding); inset is fraction of schools indicating they offered courses in this area.

The area of Process electives seems to be a fertile one for new course offerings. Most responses here reflect 2-4 schools, and this is the only grouping *not* to appear at most programs.



there is a current widespread elective course that is primed for conversion to a requirement. Possible contenders include a “bio-related” elective or undergraduate research, both of which are very widespread, although it is not clear that either has the traction required to make the switch.

A limitation of the study is that any definition of “chemical engineering elective” will not incorporate all relevant courses at all institutions. For example, depending on institutional context, a course in “materials science” may be offered in chemical engineering or it may be offered by a materials science department. The first meets our definition while the second does not, even though they are functionally the same course. It is likely that some of the programs that do not offer courses in a given area (the five answering that they offer no “Bio-Type” courses, for example) have those courses available outside the department. Another smaller limitation is that some courses that are elective for one institution are required at others; both Materials Science and Bioprocess Engineering fall into this group although there do not seem to be many others of this type.

### **Acknowledgements**

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### **Citations**

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