How We Teach: Chemical Engineering Electives

Dr. Laura P. Ford, The University of Tulsa

Laura P. Ford is an Associate Professor of Chemical Engineering at the University of Tulsa. She teaches process control and chemical engineering senior labs. She advises research in the delayed coking refinery process and TU's Engineers Without Borders - USA chapter.

Dr. Janie Brennan, Washington University in St. Louis

Janie Brennan is a Senior Lecturer of Energy, Environmental and Chemical Engineering at Washington University in St. Louis. She earned her BS in Agricultural and Biological Engineering from Purdue University in 2010, and her Ph.D. in Chemical Engineering (also from Purdue) in 2015. She teaches several core engineering courses, including thermodynamics, separations, unit operations lab, and zymurgy, and her research has focused on understanding best practices for teaching and learning in these courses.

Dr. Heather Chenette, Rose-Hulman Institute of Technology

Heather Chenette is an Associate Professor of Chemical Engineering at Rose-Hulman Institute of Technology. Her professional interests include leveraging qualitative methods to understand and enhance student learning in the classroom and creating opportunities for students to learn about polymers, membrane materials, and bioseparation processes through research experiences.

Dr. Jennifer L. Cole, Northwestern University

Jennifer L. Cole is the Assistant Chair in Chemical and Biological Engineering in the Robert R. McCormick School of Engineering and the Director of the Northwestern Center for Engineering Education Research at Northwestern University.

Dr. Kevin D. Dahm, Rowan University

Kevin Dahm is a Professor and Undergraduate Program Chair 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" with Donald Visco and "Interpreting Diffuse Reflectance and Transmittance" with his father Donald Dahm.

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

David L. Silverstein is a Professor of Chemical Engineering at the University of Kentucky where he has taught since 1999. He received his BSChE from the University of Alabama and his MS and PhD in chemical engineering from Vanderbilt University. Silverstein's research interests include conceptual learning tools and training with a special interest in faculty development. He has received the following ASEE ChE Division awards: Fahien for young faculty teaching and educational scholarship, Corcoran for best CEE article (thrice), and Martin for best ChE Division paper at the ASEE Annual Meeting.

Dr. Stephen Ward Thiel P.E., University of Cincinnati

Stephen Thiel is a Professor-Educator in the Chemical Engineering program at the University of Cincinnati (UC). He received his BS in Chemical Engineering from Virginia Tech, and his MS and PhD in Chemical Engineering from the University of Texas at Austin. His past research has focused on membrane science, adsorption, and ion exchange. He currently serves as the Chemical Engineering Undergraduate Program Director at UC and teaches the capstone process design sequence. He is a licensed Professional Engineer in the State of Ohio.

How We Teach: Chemical Engineering Electives

Abstract

The AIChE Education Division's Survey Committee covered elective course offerings in chemical engineering departments in the US and Canada in the Fall 2023 survey. Results are available from 70 respondents at 69 institutions. Medians are presented here, and the mode is mentioned if it is different from the median. Institutions require that their students take two chemical engineering elective courses, one outside-of-department technical elective (mode of zero), and four total technical electives. Undergraduate-only institutions (N = 5) offer a median of 8 chemical engineering elective courses over a two-year period, with a range of 2 to 28 courses. Over the same time frame, departments with graduate programs offer a median of 3 elective courses to just undergraduate students (mode = 2), 4 elective courses to undergraduates that graduate students may take (mode = 0), and 6 graduate courses that undergraduates may take as electives (mode = 0). Elective class sizes are small, with 44% of institutions reporting a typical enrollment of under 15 undergraduate students per course and 50% reporting 15 – 30 undergraduate students per course. In the past ten years, 17% of departments have converted a required course to an elective. These now-electives were most often required bioprocessing, advanced chemistry, or molecular engineering courses. More departments, 26%, reclassified technical electives as required courses in the past ten years. These now-required courses were usually process safety, programming, or statistics elective courses. Bio-, energy-, and materials-type electives were offered at over three-quarters of departments. Advanced-core and sustainability electives were the next most popular, at 60% of institutions. Process-type electives were offered in 47% of departments. In the past ten years, almost all departments created a new technical elective that has been regularly offered. Bio-type electives were the most common new elective, followed by process-type electives. Data analysis, data science, and process simulation & modeling were the only emerging topics to be covered in an elective course at half or more of the departments. Details about course titles, electives with laboratory components, minors & concentrations, and common out-of-department electives are provided in the proceedings. Comparisons were made to the results from previous surveys when possible.

Introduction

Electives are a win-win situation for students and faculty. Students select a few courses in their interest areas and tend to be more motivated to learn the material. Faculty get students who have chosen to be there, probably smaller course enrollments, and a course of greater personal interest to them than with required courses. These desirable courses, electives, were the topic for the AIChE Education Division (EdDiv) Course Survey Committee's Fall 2023 survey. This topic was last surveyed in 2013 [1].

We defined "Chemical Engineering Electives" as having all four of the following characteristics:

1. Courses offered by faculty associated with the chemical engineering department / program or offered primarily to students in the chemical engineering department / program.
2. Courses that may be taken by undergraduate students (may be cross-listed with a graduate course designation).

3. Courses not specifically required to graduate. Note that the courses may form part of an undergraduate requirement (ex: Each student must have 6 credits of chemical engineering electives in order to graduate).
4. Course is not a first course in any part of the traditional "chemical engineering core", including basic transport sequence (fluids, mass, and heat transfer), kinetics, design, mass and energy balances, thermodynamics, even if none of these is a specific requirement of graduation. "Advanced" courses in any of these may be considered.

We also defined "Technical electives" to include "Chemical Engineering Electives" and upper-level technical courses outside the department such as those in science, math, or other engineering, not including humanities, writing, etc.

The survey is presented in Appendix A. The survey covers elective requirements in the curriculum, changes from required courses to electives and vice-versa, new regularly offered electives, how many electives are offered, whether electives were for undergraduates only, elective topics and course titles both within the department and outside the department, elective course sizes, coverage of emerging topics in electives, electives with laboratory components, and specializations (which may be a driving force for offering electives). The results are discussed in this paper and compared with the results from 2013 [1] and earlier.

A participation request and link to the survey were distributed to department chairs through the EdDiv's chairs listserv. The request and link were also included in the EdDiv's and ASEE Chemical Engineering Division's email newsletters. Committee members sent emails to faculty in their networks to encourage more responses. Appendix B lists the 69 institutions represented in the 70 responses.

Several interesting topics were not included in the survey because their results were not likely to be actionable. One of those topics was how frequently a particular elective is offered. Many factors play into the offering frequency, such as sabbaticals, staffing changes, the need to cover required courses, and enrollment changes. Data collected in the 2013 electives survey about frequency were not usable, so we asked this time about electives that had been taught in the past two years. Recent discussion on the EdDiv chairs' listserv about electives had mentions of electives being taught every year or every other year.

Another related issue not included on the survey is how the slate of electives is chosen, given that more faculty may want to teach an elective in their research specialties than permitted by staffing and required courses. Based on recent discussion on the EdDiv chairs' listserv, departments use several methods. Junior faculty often prepare 2 - 3 courses before tenure, with one of those courses being an elective. Senior faculty often yield to letting junior faculty teach electives if there is a conflict.

A third question not included on the survey was about the procedure to get an elective approved. Based on the discussion on the EdDiv chairs' listserv, electives are usually offered as a special topics course 1 - 3 times before starting the official course approval process. These special topics courses often need only chair and perhaps departmental curriculum chair approval. A minimum enrollment (6 – 10 students were mentioned) is usually needed to become an official

course. The approval chain for official courses may include the departmental curriculum committee, the faculty, the college/school curriculum committee, and an institution curriculum committee. Courses offered for both graduate and undergraduate students require approval at both levels.

Requirements, Offerings, and Changes in Requirements

Departments may require electives from within the department and technical electives from outside the department. There may also be a requirement for total technical electives which is not the sum of the inside and outside department electives, leaving the students some flexibility. Results from 70 responding institutions regarding the number of required electives are given in Figure 1. The median values are 2 chemical engineering electives, 1 non-chemical engineering elective, and 4 total technical electives.

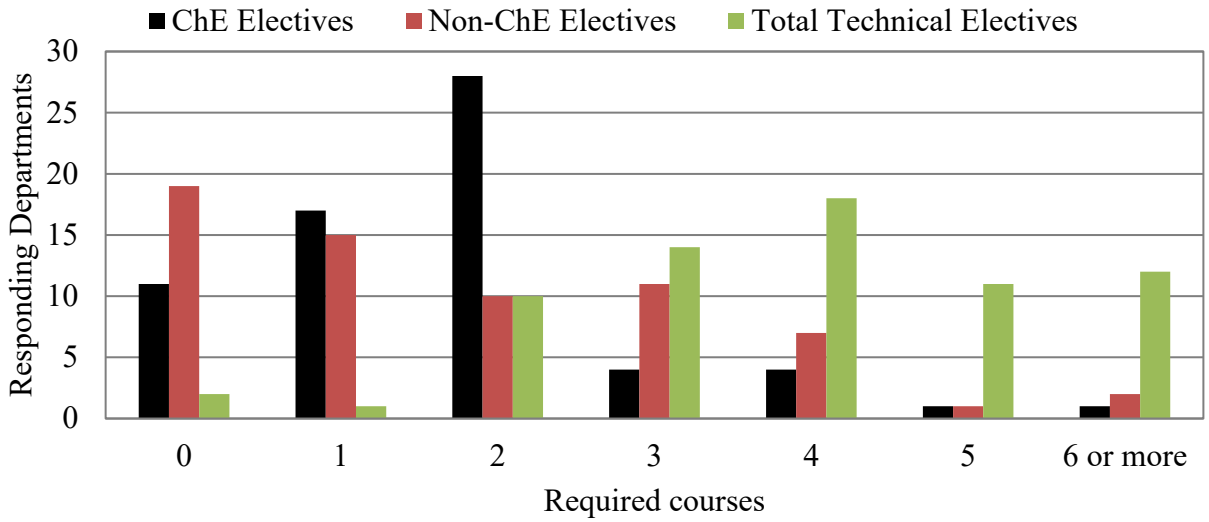

Figure 1. How many technical elective courses are required, 70 responding institutions.

A second question asked how many chemical engineering electives students take, with results shown in Figure 2 along with the distribution of the number of required chemical engineering electives. The median for both required and taken electives is two, but the distribution is skewed to higher values for the number of chemical engineering electives taken. The students may have chosen to take more chemical engineering elective courses than required to fulfill the total technical electives requirement.

In 2013, students were required to take more chemical engineering electives than in 2023. The mode and median were both 3 in 2013. Students also took about one more chemical engineering elective than required in 2013. A 2016 survey over the curriculum reported on the change in the number of required electives rather than absolute numbers. The mode was no change with 45% of departments. Almost as many departments added electives (21%) as removed electives (28%) [2].

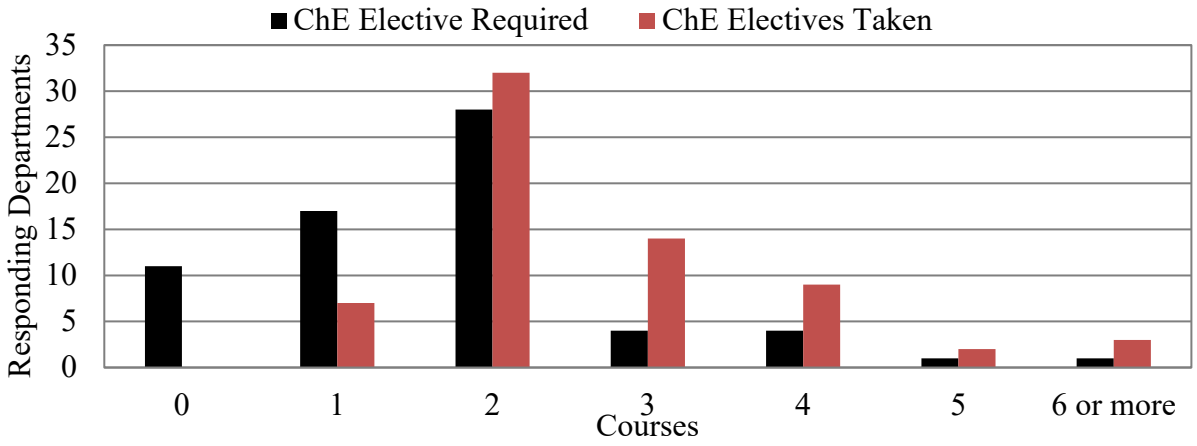

Figure 2. Approximately how many technical electives are taken by students, on average, from 68 respondents

If an institution enrolls only undergraduates, then electives are obviously taken only by undergraduates. At institutions with graduate programs, elective courses may be offered to undergraduates only as well. Electives may also be undergraduate courses that graduate students are allowed to take or graduate courses that undergraduates are allowed to take. Responses for how many courses (not sections) of different types of electives are offered are given in Figure 3. Very few responding institutions were undergraduate-only institutions ("at UG-only" series), so no trend can be detected for them. Each type of elective at institutions with graduate programs was not offered by 10 – 20% of the respondents. Departments with graduate programs tended to offer fewer undergraduate-only electives ("UG only at grad", median = 3 every two years) than undergraduate electives which graduate students may take ("UG with grad", median = 4 every two years). Programs offered more graduate electives that undergraduates could take ("Grad with UG", median = 6 every two years) than both types of undergraduate electives.

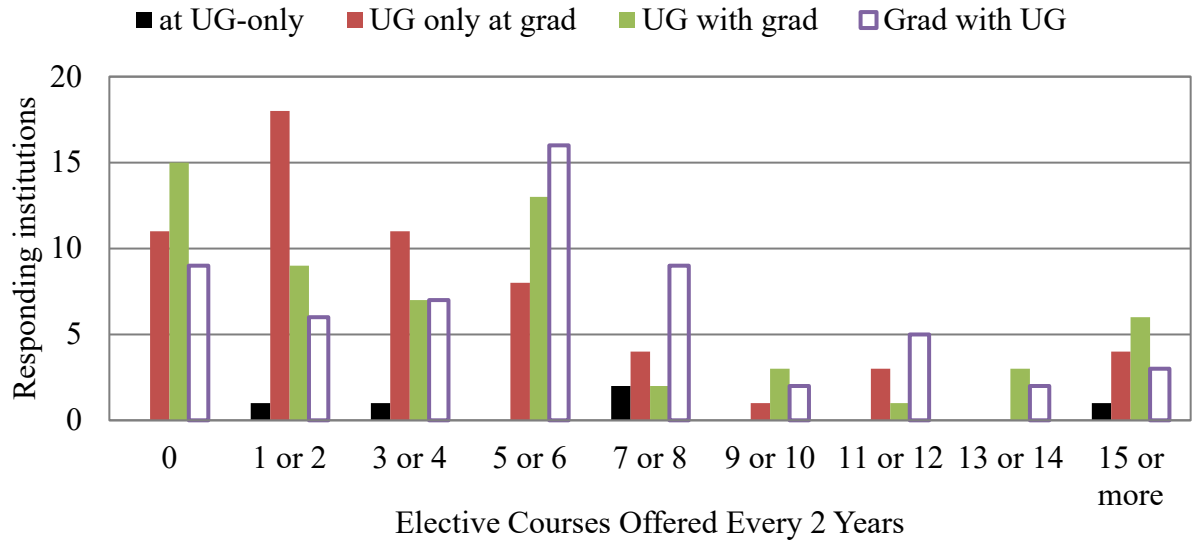

Figure 3. Number of elective courses (not sections) offered over a two-year period, 69 respondents

Undergraduate enrollment in chemical engineering elective courses tends to be small. With 69 respondents, only 6% of respondents had 31 or more undergraduates in a typical elective course in the past two years. Half of the institutions reported a typical undergraduate enrollment of 15 – 30, and 44% had 1 – 14 undergraduates in chemical engineering electives. Elective enrollments are smaller than they were in 2013, when 32% of courses had 1 – 14 students; 51%, 15 – 30; 11% 31 – 50, and 2%, 51 – 75; and 4% over 75.

We were interested in knowing which required courses had become electives and which electives had become required in the ten years since the previous survey on electives [1]. Most departments reported no changes between required and elective courses. Of 69 responding departments, 26% had a course change from elective to required in the past ten years. Process safety was the most common elective-to-required move with five institutions. Programming and statistics electives were made required at three institutions each in the past ten years. Other classes which became required were quality engineering; process design, economics, & simulation; simulation of chemical processes; laboratory electronics for nuclear, chemical, and biological engineers; biomolecular engineering; biochemical engineering; principles of biology; and organic chemistry.

Required courses became elective courses at 17% of 70 responding institutions in the past ten years. These courses were more diverse, with two institutions each making bioprocess engineering, Physical Chemistry II, and molecular engineering optional. Other courses becoming electives were Separation Processes III, advanced transport phenomena, biomedical engineering, introduction to biotechnology, Physical Chemistry III, Organic Chemistry II, mineral processing, particle technology, and semiconductor materials.

Offered Electives

Chemical engineering programs offer electives in a wide range of topics, as shown in Figure 4. For the 70 respondents, no one category of elective was offered at every institution, but bio-related courses were the most commonly offered electives. Materials and energy electives were also very common, at more than 75% of the institutions. Specifics about the courses in each category are given in the next several figures. Data from 2013 are included in Figure 4 for comparison. The survey in 2013 did not include sustainability-type electives as a separate category. Advanced core-type electives were offered in 20% fewer departments in 2023 than in 2013, and materials-type electives were in about 10% fewer departments. The fractions of departments offering the rest of the categories have not changed much in the past decade.

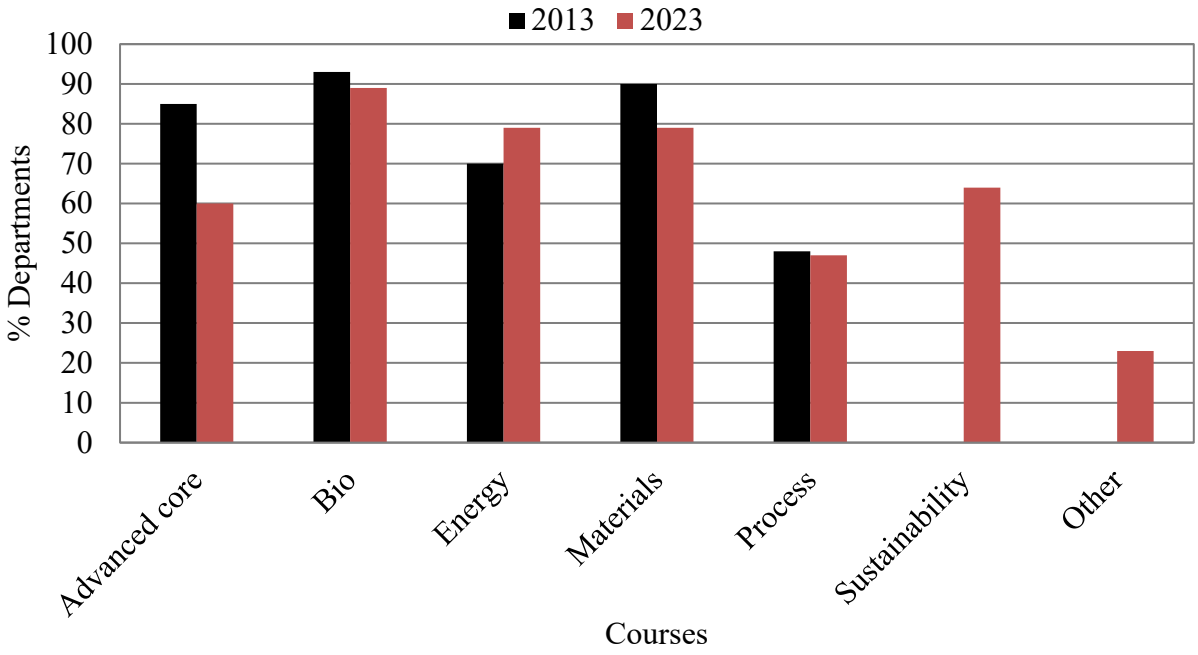

Figure 4. Percent of departments offering different categories of electives over the past two years, 70 respondents

At the 42 institutions offering advanced core electives, the most popular electives were advanced transport and research/projects, as shown in Figure 5. The "other" category included 7% who offered engineering math/statistics as an advanced core elective.

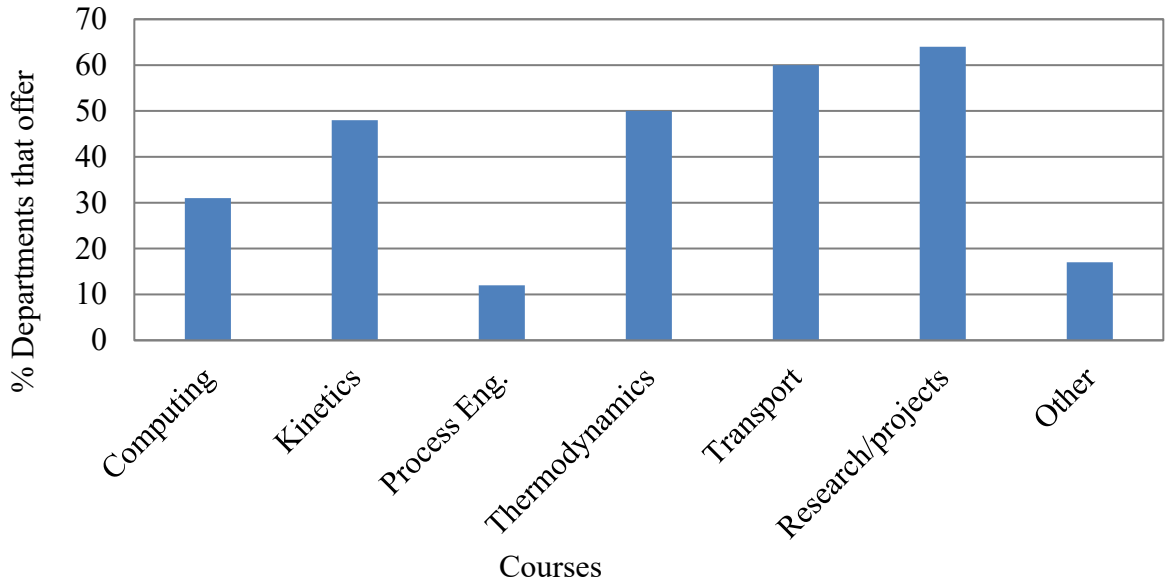

Figure 5. Advanced core electives offered by the 42 respondents with this type of elective

Within the bio-type electives offered at 62 institutions, bioprocess engineering was the most popular elective (Figure 6). Biochemical engineering and cellular engineering each accounted for 7% in the 32% "other" category.

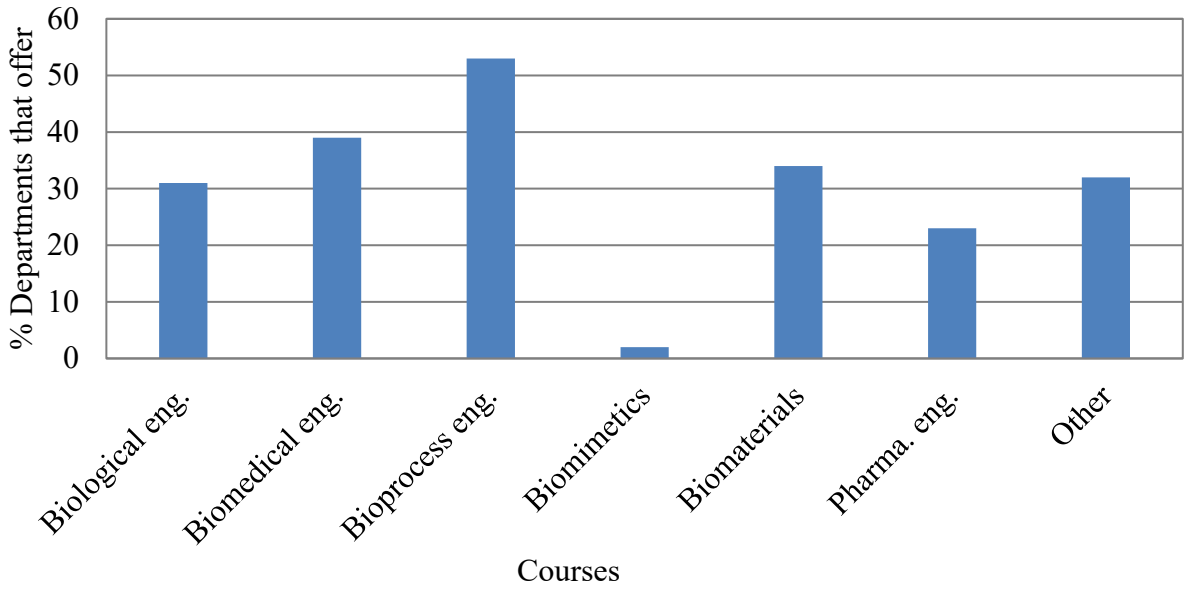

Figure 6. Bio-type electives offered by the 62 respondents with this type of elective

Energy electives were offered at 55 institutions, and the breakdown of those electives is presented in Figure 7. Electrochemistry and sustainable energy were the most frequently offered energy electives.

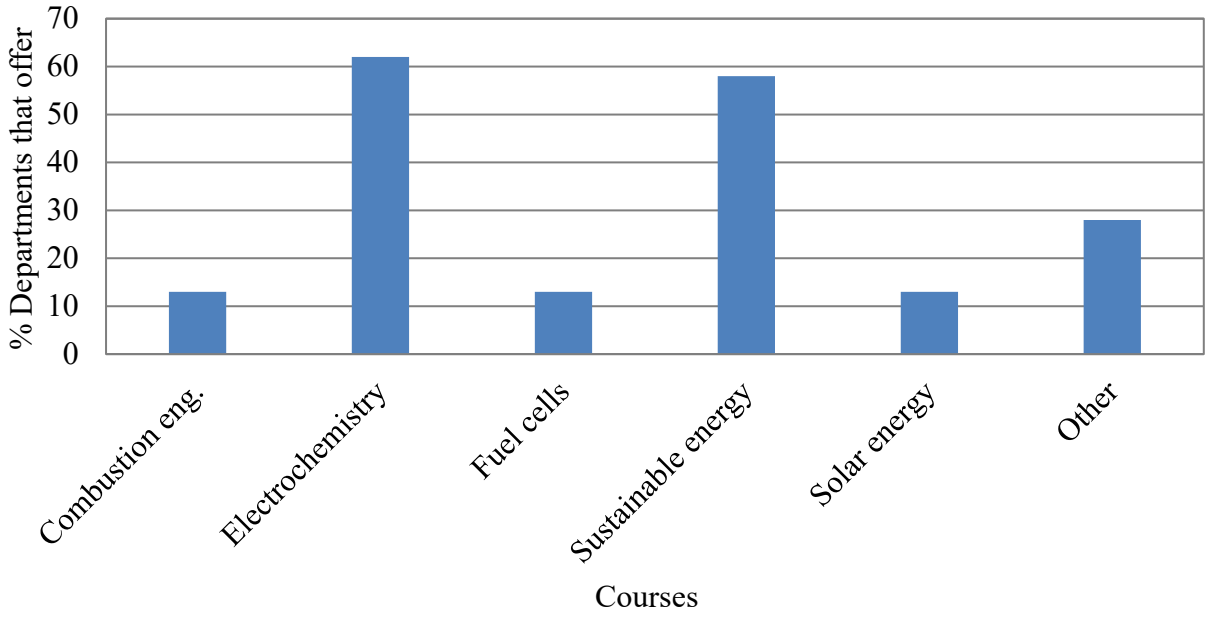

Figure 7. Energy electives offered at 55 institutions

Materials electives were also offered at 55 institutions, and the distribution of those electives is given in Figure 8. Polymer science and/or engineering is the most popular materials science elective.

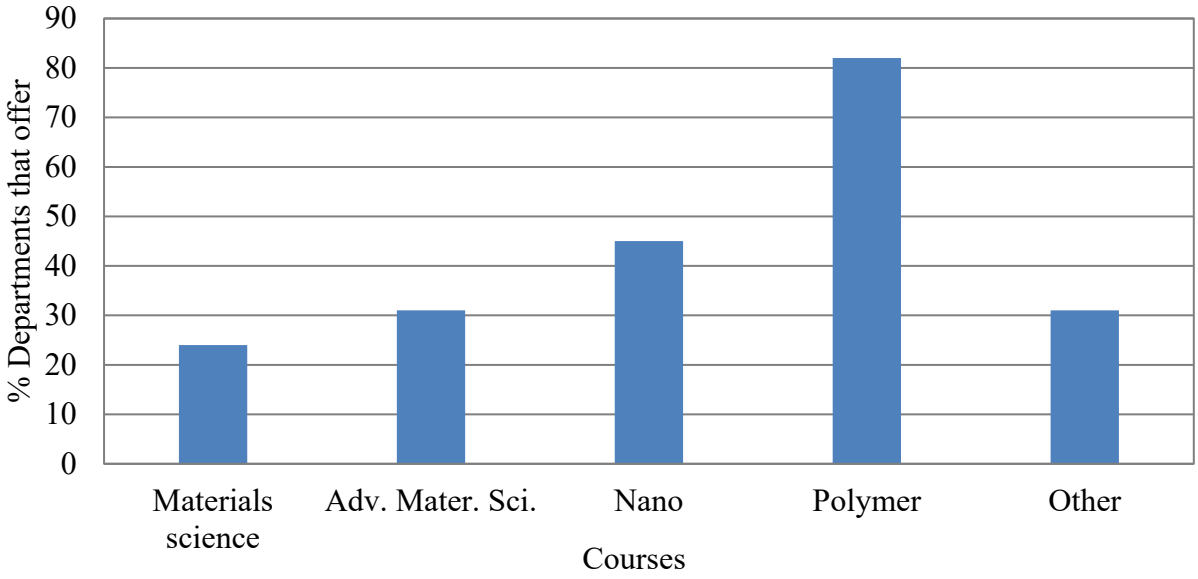

Figure 8. Materials science electives offered at 55 institutions

Process-type electives were the least popular electives, offered by only 33 of our 70 respondents (Figure 9). Product design and an elective controls course were the most common in this category, but the "other" category was the largest response. There was a wide variety of "other" responses, with process data science/machine learning/analytics making up 7% of the 51% "other" response.

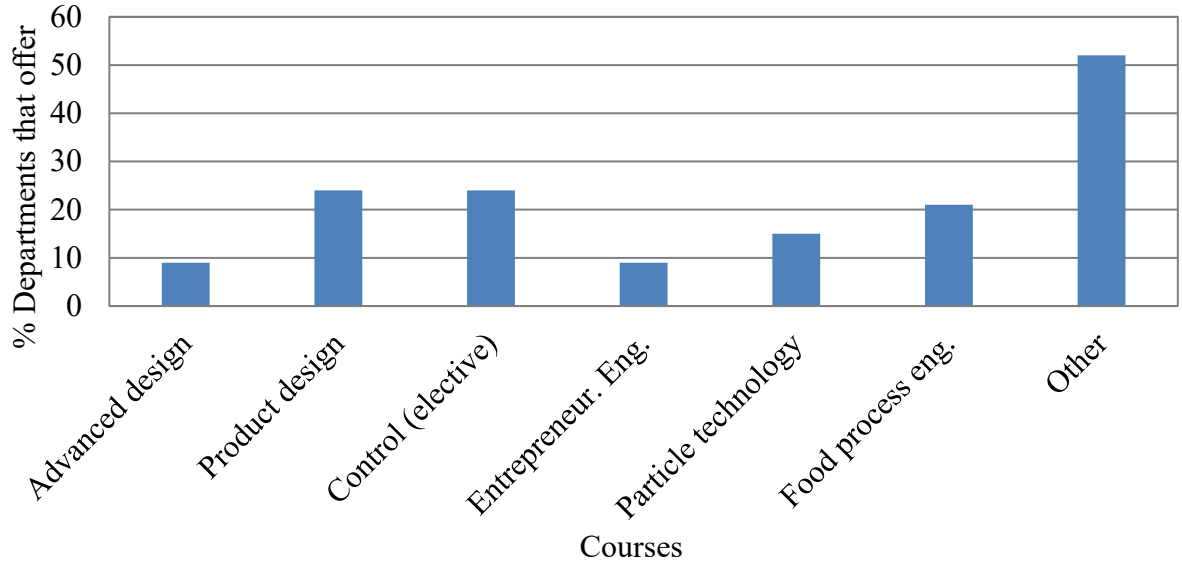

Figure 9. Process-type electives offered at 33 institutions

Sustainability-type electives were offered by 45 institutions, and the courses are presented in Figure 10. There is some overlap with the energy-type electives in Figure 7. In comparing the two figures, remember that in Figure 7 percentages are out of 55 institutions and Figure 10 is out of 45 institutions.

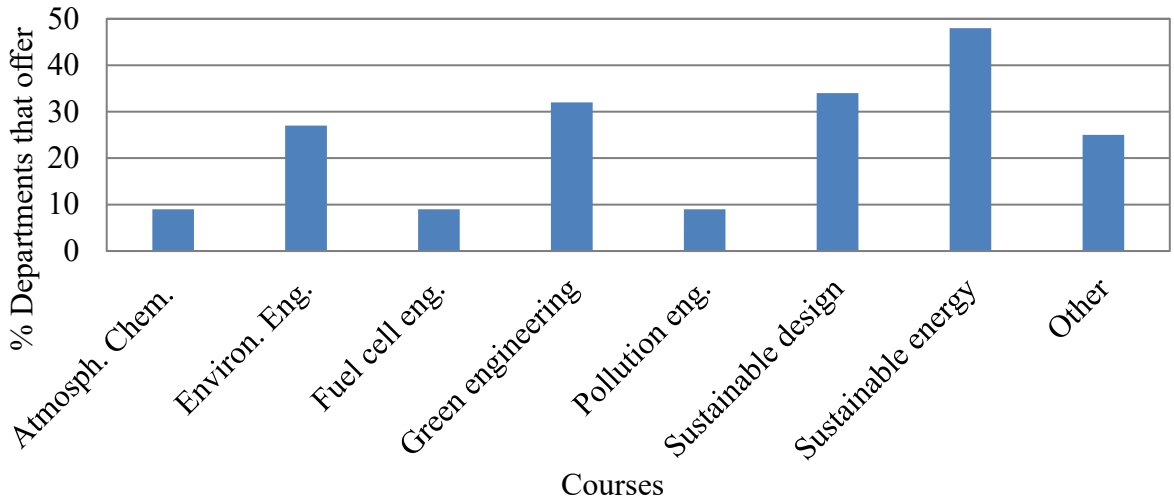

Figure 10. Sustainability-type electives offered by 45 institutions

Of the eight most popular electives, shown in Figure 11, only polymer science & engineering was taught at more than half of the responding institutions in 2023. Bioprocess engineering, electrochemistry, and sustainable engineering were taught by over 40% of respondents. Data from 2013 are included for comparison. Note that electrochemistry was not listed as a course in the 2013 survey. Most changes from 2013 are likely within measurement uncertainty, but there was a large decline in departments offering student projects or research as an elective. Chemical engineering electives were and are diverse.

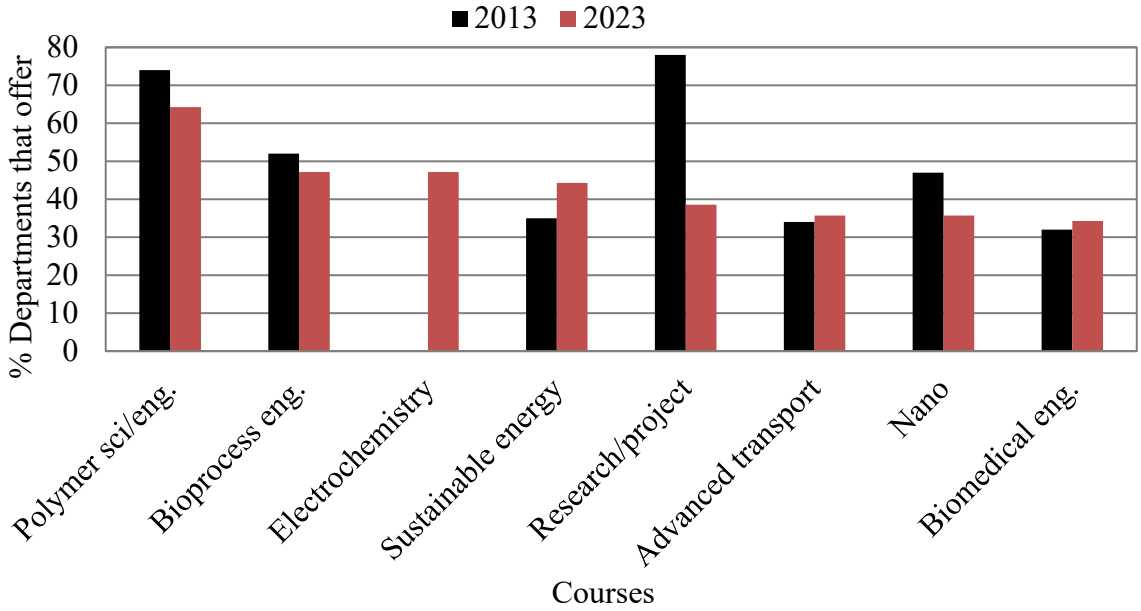

Figure 11. Percent of institutions that teach the eight most popular elective courses, 70 respondents

New Electives

New, regularly-offered electives have been developed at 90% of the responding institutions. These new electives were grouped according to the categories in Figure 4, with the addition of process safety as its own category. Just as bio-type electives were the most commonly offered electives (Figure 4), they were also the most commonly added new electives (Figure 12). Although process-type electives were the lowest category in Figure 4, they were the second most commonly added category of new electives.

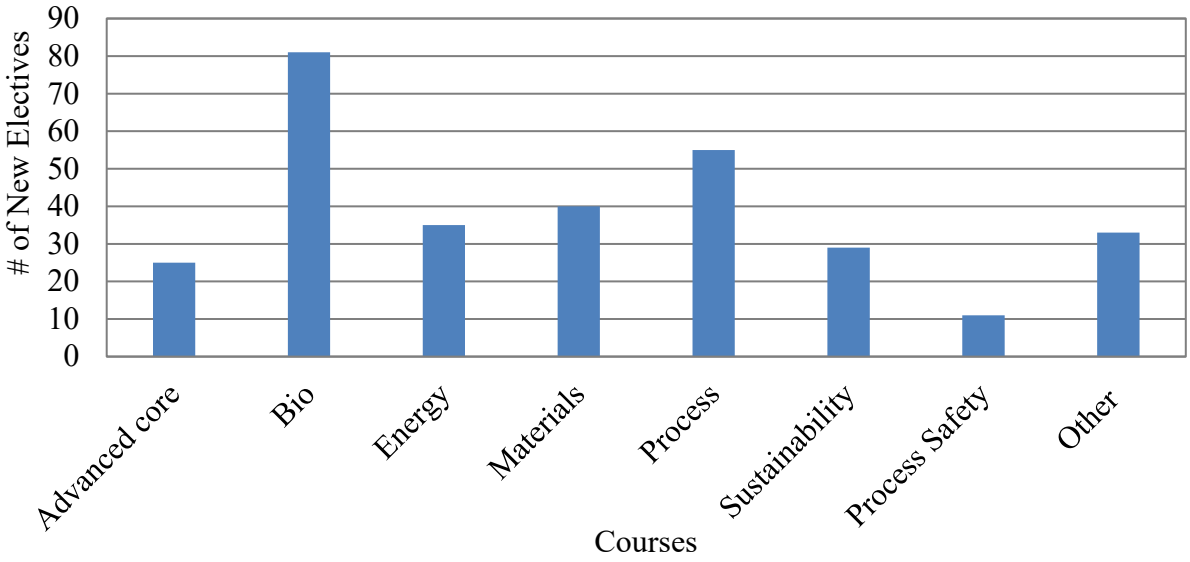

Figure 12. New regularly-offered electives, 70 institutions, 308 courses

Similar to Figure 11, the new top 11 new electives in Figure 12 are presented in Figure 13. Some interesting entries in this list of new electives are pharma, data science/machine learning, and food & spirits.

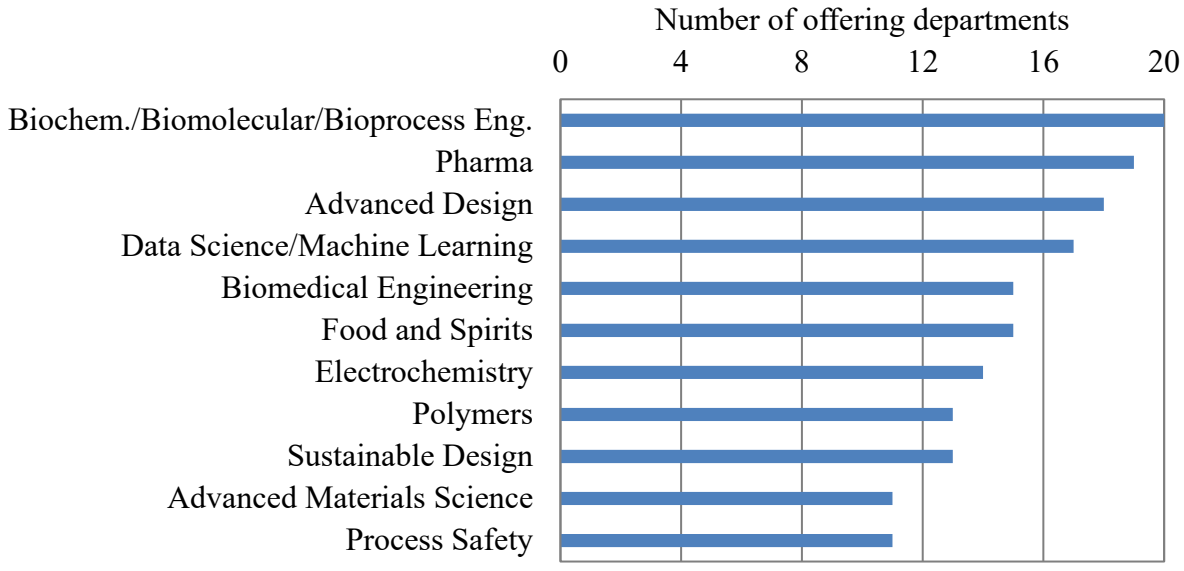

Figure 13. The number of departments regularly offering the top 11 new electives

The committee asked about data science, machine learning, and other potentially emerging topics in all chemical engineering electives, not just new electives. We asked if the topics in Figure 14 were not covered in any elective or were a minor part of an elective, a substantial part, or an entire elective course. Electives in process modeling/simulation, data science, and data analysis are offered at about 20% of responding institutions, and 50% of responding departments have these topics as at least a minor part of an elective.

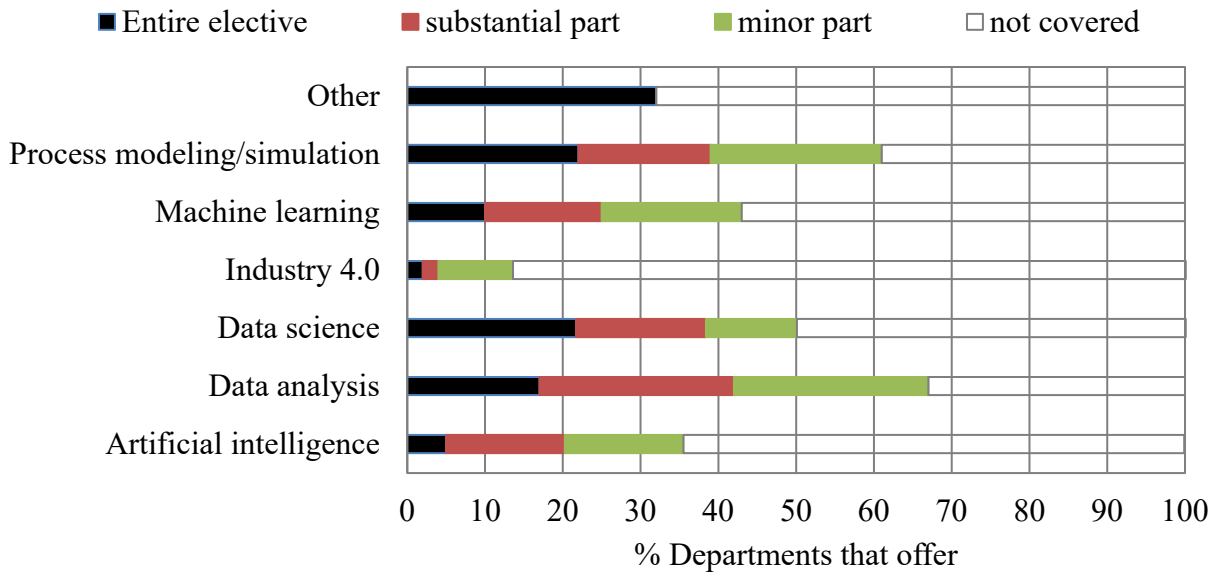

Figure 14. Coverage of emerging topics in chemical engineering electives, about 60 responses

Electives Outside of the Department

As noted in the discussion for Figure 1, students are required to take a median of 1 elective outside of the department and 4 total technical electives. Electives taken outside of the department, whether or not for a degree requirement, were reported by 56 institutions. Departments were allowed to list up to five top outside electives. These outside electives were categorized in Figure 15. Chemistry & biochemistry was the most common category of elective by a factor of two. The next three most common outside elective categories were environmental engineering, mathematics, and biology.

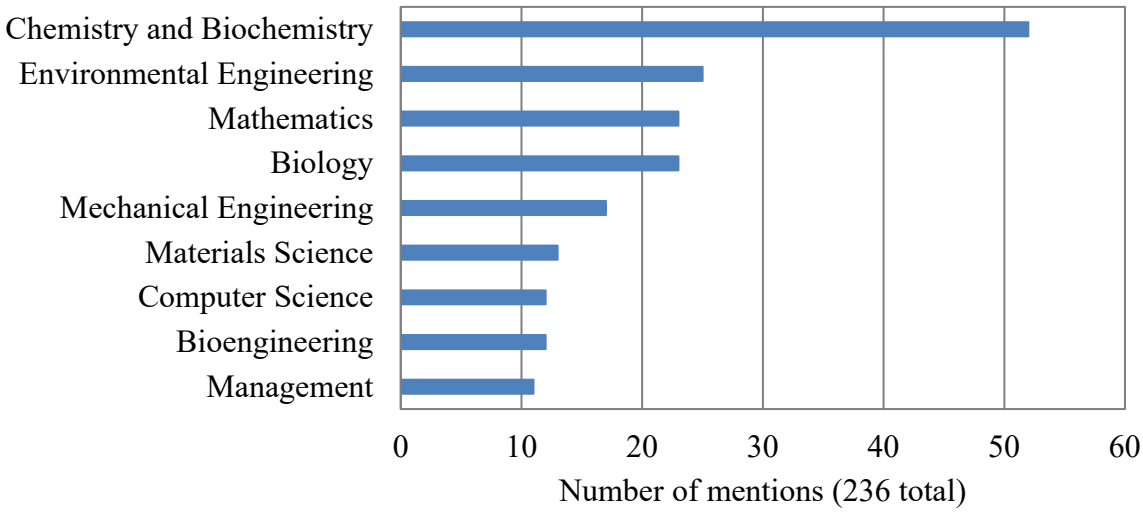

Figure 15. Electives taken from outside of the department at 56 institutions

The list of 236 outside-of-department electives were also counted by course, which is presented in Figure 16. Biochemistry was the most common elective taken outside of the department by almost a factor of two.

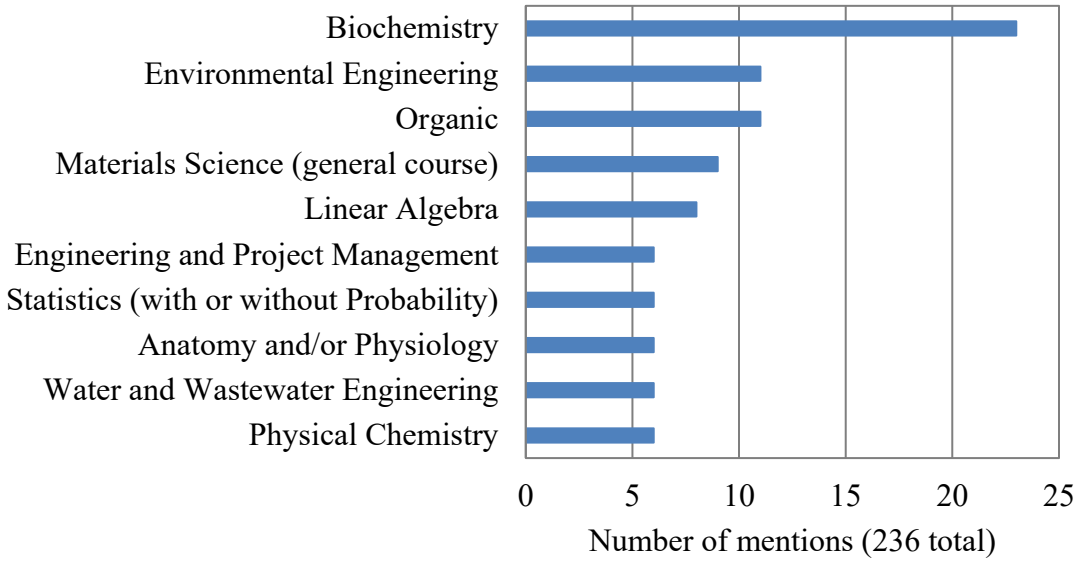

Figure 16. Elective courses taken outside of the department, 56 institutions

Electives with Labs

Most departments (89%, 70 respondents) do not require that any electives be lab-intensive courses. In the 11% of departments which do require lab-intensive electives, commonly taken courses were sciences, battery systems, environmental engineering, digital process controls, and micro-electro-mechanical systems. There are some electives that do routinely incorporate a lab component, either officially or unofficially, and those are described in Figure 17. More departments reported bio-type electives with lab components than other categories.

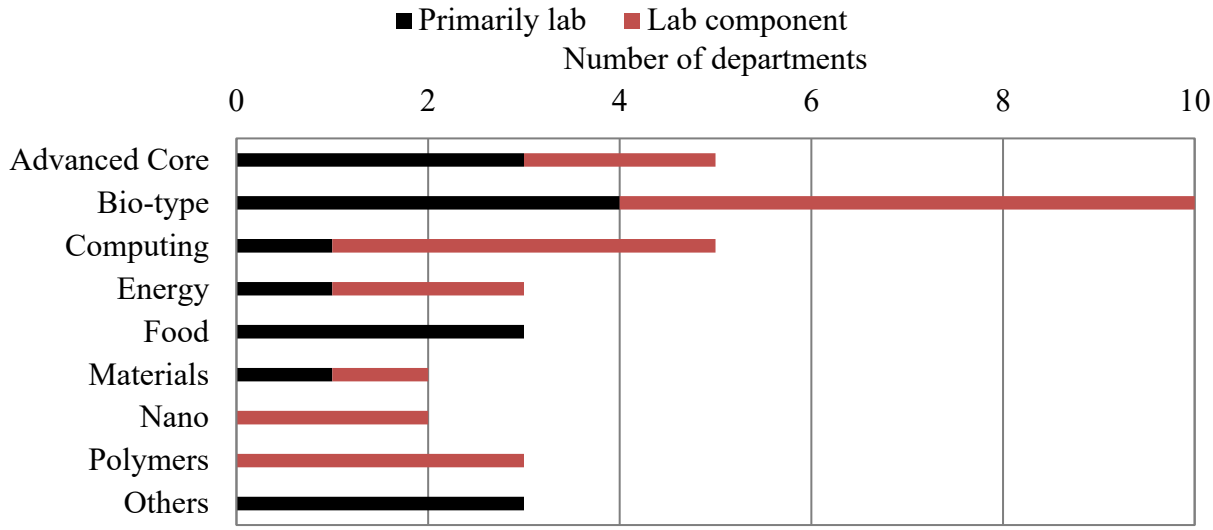

Figure 17. Electives which routinely incorporate a lab component, 27 respondents

Specializations

We were also interested to see if electives align with specializations offered by departments. Two-thirds of the 70 respondents offered a minor, concentration, emphasis, or other type of distinction, with details presented in Table 1. Minors are offered by more responding departments than the other types of specializations, but departments offer more concentrations per department than minors per department. The most common specializations are bio-related, environmental, or materials-related, which aligns well with the electives offered. In 2016, 70% of departments responding to the curriculum survey had a specialization of some type, and the most common were bio-related topics (bioengineering, pharmaceutical, biomed), energy-related, polymers, pre-med, and materials [2].

Table 1. Data for specializations offered by departments, 70 respondents

	Minor	Concentration	Emphasis/Other
Number of departments	20	16	12
Total offered	29	61	19
Offered/dept	1.5	3.8	1.6
Most common	Materials Biochemical Biomedical	Materials Environmental Biomolecular	Biochemical Environmental

We were curious if students in departments which do not offer a specialization still have a variety of elective offerings, or if electives were offered mainly to satisfy the requirements for specializations. Table 2 presents the number of institutions offering courses within a specialization (from Figure 4) broken down by whether or not they offer specialization in that area. There is some positive correlation between offering a specialization in an area and offering

electives in that area, but 60% or more of departments who do not offer a specialization still offer an elective in the area.

Table 2. Institutions offering electives within specialization areas, broken out by those who offer specializations and those who do not

	Percent offering (#) with specialization	Percent offering (#) without specialization
Bio-related	94% (33 of 35)	82% (27 of 33)
Environmental/Sustainability	79% (15 of 19)	60% (30 of 50)
Materials	80% (20 of 25)	80% (35 of 44)

Summary

Chemical engineering departments require a median of 2 chemical engineering electives, 1 non-chemical engineering elective, and a total of 4 technical electives. Elective courses tend to be small, with undergraduate enrollments under 30 at 94% of responding institutions. Electives are not frequently converted to required courses (26% of respondents), but process safety was the more common former elective to be made a requirement. Fewer institutions converted required courses to electives (17%). The electives offered are diverse, with no one category offered at all 69 responding institutions. Bio, energy, and materials electives were offered at more than 75% of responding institutions. The elective offered at the most departments was polymer science and/or engineering, and it was the only elective offered at more than 50% of the responding institutions. Bio-type electives were the most common new electives, and chemistry & biochemistry was the most common elective category taken outside of the department. Electives have some coverage of the emerging topics of process modeling & simulation, data science, and/or data analysis at over 50% of responding institutions. Many aspects of electives have remained the same since the 2013 survey. The main changes have been a decrease in required electives from 3 to 2, smaller elective class sizes, and a decrease in the percentage of programs offering research or projects as an elective.

References

[1] M. A. Vigeant and D. L. Silverstein, "Results from the AIChE Education Annual Survey: Chemical Engineering Electives," in *ASEE Annual Conference and Exposition*, Indianapolis, IN, 2014.

[2] M. A. Vigeant, K. D. Dahm and D. L. Silverstein, "The state of the chemical engineering curriculum: Report from the 2016 survey," in *ASEE Annual Conference and Exposition*, Columbus,OH, 2017.

Appendix A: AIChE EdDiv Electives Survey

Q1 Thank you very much for responding to this survey. The AIChE Education Division Survey Committee asks departments yearly about the current state of undergraduate education in a particular area of chemical engineering. This year, we are focusing on electives. We hope that this survey can be fully completed as Qualtrics predicts in 12 minutes or less by someone familiar with the course offerings, but we think Qualtrics underestimates.
Previous recent surveys have been on Capstone Design, Material & Energy Balances, the First-year Experience, Unit Operations Laboratory, Thermodynamics, Design, Transport, Controls, Kinetics and Reactor Design, and the curriculum as a whole. Our collected publications archive is available through this Google drive link.

Questions? Please contact Laura Ford (committee chair) at laura-ford@utulsa.edu. Thank you for your help!

Q2 First, we'll ask some questions about you, your department, and your program in general.

Q3 Name of your institution

_____

Q4 Name of the person completing the survey

_____

Q5 Does your institution use quarters, trimesters, semesters, or another system?

- Quarters
- Trimesters
- Semesters
- Other (please describe) _____

Q6 Number of faculty and instructors who teach in your department.
(Please include professors of practice, visitors, adjuncts, instructors, and tenured/tenure track; please do not include graduate teaching assistants or research faculty.)

_____

Q7 Does your department offer more than one undergraduate degree program? (for example: Chemical Engineering and Biochemical Engineering)? NOTE - this is asking about degree title only, not minors, concentrations, or certificates. Most programs offer only one undergraduate degree.

- Yes
- No

Display This Question:If Q7 = Yes

Q8 Name of the undergraduate degree program used as a basis for these answers (note - this question is to accommodate departments offering multiple degree programs - such as Chemical Engineering and Materials Engineering - within one department. We recognize most programs

only offer one degree. If your department offers multiple undergraduate degree programs, please consider re-answering this survey once for each of these programs).

Q9 About how many undergraduates have graduated from your program per year recently, on average

- 1 - 20
- 21 - 40
- 41 - 60
- 61 - 80
- 81 - 100
- 101 - 120
- 121 - 140
- 141 - 160
- 161 - 180
- 181 - 200
- more than 200

Q10 Does your department have a graduate program?

- Yes
- No

Q11
This survey asks about two kinds of electives: "Chemical Engineering Electives" and "Technical Electives". We define "Chemical Engineering Electives" as having all four of the following characteristics:

- Courses offered by faculty associated with the chemical engineering department / program or offered primarily to students in the chemical engineering department / program.

- Courses that may be taken by undergraduate students (may be cross-listed with a graduate course designation).

- Courses not specifically required to graduate. Note that the courses may form part of an undergraduate requirement (ex: Each student must have 6 credits of chemical engineering electives in order to graduate).

- Course is not a first course in any part of the traditional "chemical engineering core", including basic transport sequence (fluids, mass, and heat transfer), kinetics, design, mass and energy balances, thermodynamics, even if none of these is a specific requirement of graduation. "Advanced" courses in any of these may be considered.

"Technical electives" include "Chemical Engineering Electives" and upper-level technical courses outside the department such as those in science, math, or other engineering, not including humanities, writing, etc.

Q12 How many "Technical Elective" courses does your program's curriculum require?

- In-department (Chemical Engineering) _____
- Out-of-department Technical Electives _____
- Total Technical Electives (may or may not be the sum of above) _____

Q13 About how many Chemical Engineering Elective courses does each student take, on average?

Display This Question:If Q10 = No

Q14 In a typical academic year, how many different Chemical Engineering Elective courses are available? (note: two sections of the same course count as one course).

_____

Display This Question:If Q10 = Yes

Q15 Over the past two academic years, how many Chemical Engineering Elective courses of each type have been offered for undergraduates? Multiple sections count as one course.

- Undergraduate-only courses _____
- Undergraduate courses which graduate students may take _____
- Graduate courses which undergraduate students may take _____

Q16 Thinking over the last two academic years, approximately how many undergraduate students were enrolled in a typical Chemical Engineering Elective, on average?

- 1 - 14
- 15 - 30
- 31 - 50
- 51 - 75
- more than 75

Q17 In the past ten years, have any courses that were formerly required courses been re-classified as Technical Electives?

- Yes
- No

Display This Question:If Q17 = Yes

Q18 Please name the course(s) that in the past ten years were converted from required courses to Technical Electives.

_____

Q19 In the past ten years, have any courses that were formerly Technical Electives been re-classified as required courses?

- Yes
- No

Display This Question:If Q19 = Yes

Q20 Please name the course(s) that in the past ten years were converted from Technical Electives to required courses.

_____

Q21 In the past ten years, have any new courses been created and regularly offered as Technical Electives by your department?

- Yes
- No

Display This Question:If Q21 = Yes

Q22 Please name the new Technical Electives developed in the past ten years and now regularly offered by your department.

_____

Q23
The following blocks of questions ask you to select and/or supply the electives your department has offered within the past two years. We will first ask about broad categories and then follow up with specific courses. We have supplied "typical" names for some typical electives.

Electives are grouped into categories to make it easier for you to find them. Some appear in multiple categories, but you need only check each elective once.

Extra spaces are provided for you to add electives that are not included in the list.

Q24 Which categories of electives has your department offered in the past two years, if any?

- ☐ "Advanced cores-type" electives
- ☐ "Bio"-type electives
- ☐ "Energy"-type electives
- ☐ "Materials"-type electives
- ☐ "Process"-type electives
- ☐ "Sustainability"-type electives
- ☐ Other (details requested later)

Display This Question:If Q24 ="Advanced cores-type" electives

Q25 Which Advanced Core-type electives did you offer in the past two years?

- ☐ Advanced computing
- ☐ Advanced kinetics
- ☐ Advanced process engineering
- ☐ Advanced thermodynamics
- ☐ Advanced transport
- ☐ Student research / student project for credit (elective)
- ☐ Other (please name) _____

Display This Question:If Q24 ="Bio"-type electives

Q26 Which Bio-type electives did you offer in the past two years?

- ☐ Biological engineering
- ☐ Biomedical engineering
- ☐ Bioprocess engineering
- ☐ Biomimetics
- ☐ Biomaterials
- ☐ Pharmaceutical engineering
- ☐ Other (please name) _____

Display This Question:If Q24 = "Energy"-type electives

Q27 Which Energy-type electives did you offer in the past two years?

- ☐ Combustion engineering
- ☐ Electrochemistry
- ☐ Fuel cells
- ☐ Sustainable energy
- ☐ Solar energy
- ☐ Other (please name) _____

Display This Question:If Q24 = "Materials"-type electives

Q28 Which Materials-type electives did you offer in the past two years?

- ☐ Materials science (elective)
- ☐ Advanced materials science
- ☐ Nanoscience and/or nanomaterials
- ☐ Polymer science and/or engineering
- ☐ Other (please name) _____

Display This Question:If Q24 = "Process"-type electives

Q29 Which Process-type electives did you offer in the past two years?

- ☐ Advanced design
- ☐ Chemical product design
- ☐ Control (elective)
- ☐ Entrepreneurial engineering
- ☐ Particle technology
- ☐ Food process engineering
- ☐ Other (please name) _____

Display This Question:If Q24 = "Sustainability"-type electives

Q30 Which Sustainability-type electives did you offer in the past two years?

- ☐ Atmospheric chemistry
- ☐ Environmental engineering
- ☐ Fuel cell engineering
- ☐ Green engineering
- ☐ Pollution engineering
- ☐ Sustainable design
- ☐ Sustainable energy
- ☐ Other (please name) _____

Display This Question:If Q24 = Other (details requested later)

Q31 Please enter the name of any elective courses offered in the past two years that were not included above or the names above were not sufficiently close to your course titles

_____

Q32 Do you offer Chemical Engineering Electives with coverage of these emerging topics?

	An entire elective course	substantial part of an elective	minor part of an elective	not covered in any elective
Artificial intelligence	☐	☐	☐	☐
Data analysis	☐	☐	☐	☐
Data science	☐	☐	☐	☐
Industry 4.0	☐	☐	☐	☐
Machine learning	☐	☐	☐	☐
Process modeling/simulation	☐	☐	☐	☐
Other emerging computing role(s) in ChE (please name)	☐	☐	☐	☐

Q33 Whether required for degree completion or not, if your students generally enroll in out-of-department **technical electives** (upper-level engineering/science/math, not including humanities, writing, etc.), please provide the names of five of those electives most commonly taken:

_____

Q34 Does your department require any of your **technical electives** (upper-level engineering/science/math, not including humanities, writing, etc.) to be laboratory-intensive?

- ○ Yes
- ○ No

Display This Question:If Q34 = Yes

Q35 Please briefly describe the laboratory-intensive elective requirement and what courses are commonly taken

_____

Display This Question:If Q34 = No

Q36 If there are electives in your curriculum that routinely incorporate a lab component (whether official or unofficial), please briefly describe the course

_____

Q37 Some departments offer concentrations, certificates, minors, or other similar distinctions for students who group their electives along a particular theme or concept. Does your department offer something like this?

- ○ Yes
- ○ No

Display This Question:If Q37 = Yes

Q38 Please describe your concentration, certificate, minor, or similar program and how any elective courses fit into the program, such as "a biomedical engineering minor in which the students take the biomedical engineering elective course and seminar we offer, two biology courses, and a selection of courses from chemistry, biology, engineering, and/or math".

_____

Q39 Any comments regarding this survey are welcome here.

_____

Q40 We thank you for your participation! This helps all of us better understand the state-of-the-art in chemical engineering education. Please join us at Session 129 at the AIChE Annual Meeting, Tuesday 8:00 am, to hear the results.

Q41 We will be compiling the results of this survey for distribution at the AIChE Annual Meeting and the ASEE Annual Conference. Would you like a copy of the processed results?

- Yes
- No

Display This Question:If Q41 = Yes

Q42 Please enter your email address so we may send you results. Your email address will not be used for any other reason.

_____

Appendix B: Responding Institutions

Auburn University
Benedictine College
Brigham Young University (BYU)
Bucknell University
California Baptist University
Caltech
Christian Brothers University
Clarkson University
Clemson University
Colorado School of Mines
Columbia University
Cornell University
Drexel University
FAMU-FSU College of Engineering
Iowa State University
Lafayette College
Lamar University
Lehigh University
Michigan State University
Missouri University of Science & Technology
New Jersey Institute of Technology
New Mexico State University
New York University
North Carolina State University
Northeastern University
Northwestern University
Oklahoma State University
Penn State
Purdue University
Rose-Hulman Institute of Technology
Rowan University
South Dakota School of Mines and Technology
Syracuse University
Texas A&M University Kingsville
The Cooper Union
The Ohio State University
The University of Tulsa
Trine University
Tufts University
Tulane University
University at Buffalo, SUNY
University of Arizona
University of Arkansas
University of Connecticut
University of Dayton
University of Delaware
University of Florida
University of Kansas
University of Kentucky
University of Louisville
University of Michigan
University of Minnesota Duluth
University of New Mexico
University of North Dakota
University of Oklahoma
University of Pennsylvania
University of South Alabama
University of Tennessee, Knoxville
University of Texas at Austin
University of Texas at San Antonio
University of Toledo
University of Utah
University of Virginia
University of Washington
Vanderbilt University
Washington State University
Washington University in St. Louis
Worcester Polytechnic Institute
Youngstown State University