INTERIM REPORT FOR CHEMICAL ENGINEERING'S UNDERGRADUATE PROGRAM FOR THE PERIOD 2015-2020.

This interim report is an excerpt from Chemical Engineering's draft 2020-2021 ABET Self Study Report. In this section of that report, each of the learning outcomes listed below is assessed and evaluated for attainment. The data used here spans the period from Fall Semester 2015 to Spring Semester 2020. This report is only for the undergraduate program.

The program outcomes are statements that describe what students are expected to know and be able to do by the time of graduation. By the time of graduation, student will have

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. an ability to communicate effectively with a range of audiences
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

CRITERION 4. CONTINUOUS IMPROVEMENT

The main sources of data for outcome assessment include

- Assessment of student outcomes by chemical engineering instructors
- Senior Exit Interviews
- Assessment of students' performance by employers (co-ops and internships)
- Fundamentals of Engineering (FE) Examination (Chemical)
- Industrial Advisory Board
- Feedback from visitors
- Graduate Council Review
- Assessment of students in the Engineering Math Sequence

Data from these sources is processed by the ABET and Undergraduate Committees.
Table 4 – 1 provides a more detailed summary of the available assessment data and its evaluation. Table 4 – 1 includes the frequency of data collection, the evaluators of the data, and the outcomes that are related to it.

Table 4 - 1. Assessment Data and Its Evaluation

Data	Frequency of Assessment	Evaluators	Outcomes
Performance of students in classes and labs	Every semester	Instructors, Geoff Silcox	1 - 7
Senior Exit Interviews	Annual	Geoff Silcox, Eric Eddings	Communication (3), professionalism and ethics (4), teamwork (5), continuous learning (7)
Performance of students in co-ops and internships	Every semester	Employers, Geoff Silcox	Teamwork (5), professionalism and ethics (4), overall preparation (1 - 3, 6 , 7)
FE (Chemical) Exam	Annual	Geoff Silcox	Identify, formulate, solve (1), design (2), ethical, professional (4)
Industrial Advisory Board and academic visitors	Annual	Geoff Silcox, Eric Eddings	1 - 7
Performance of students in engineering math sequence	Annual	Will Nesse, Geoff Silcox	Apply math (1)
Graduate Council Review	Every 7 years	Geoff Silcox, Eric Eddings	1 - 7

Expected Level of Attainment for Student Outcomes

The student outcomes are rated for their expected level of attainment using Anderson's modification of Bloom's taxonomy (Krathwohl, D. R. A Revision of Bloom's Taxonomy: An Overview. Theory into Practice. 2002, 41, (4), 212-218). The skill levels of Bloom / Anderson's taxonomy are summarized in Table 4 – 2.

Table 4 - 2. Bloom / Anderson Taxonomy Where Create (6) Is the Highest Skill Level and Remember (1) Is the Lowest

Skill Level	Description	Illustrative Verbs
6. Create	Reorganize elements into a new pattern, structure, or purpose	Generate, plan, produce
5. Evaluate	Come to a conclusion about something based on standards or criteria	Check, critique, judge

4. Analyze	Subdivide content into meaningful parts and relate the parts	Differentiate, organize, attribute
3. Apply	Use learned material to solve problems or complete tasks in new situations	Execute, implement
2. Understand	Construct new meaning by mixing new material with existing ideas	Interpret, exemplify, classify, summarize, infer, compare, explain
1. Remember	Retrieve pertinent facts from long term memory	Recognize, recall

The expected levels of attainment for the outcomes 1 - 7, based on the taxonomy in Table 4 - 2, are summarized in Table 4 – 3. The expected levels are based on those for the 5 core, 4th year courses, CH EN 4203, 4353, 4903, 4905, and 5253. These levels are set primarily by the instructors, in consultation with the Chair of the ABET Committee.

Table 4 - 3 Expected Levels of Attainment for Outcomes 1 - 7 Using Skill Levels in Table 4 - 2

Outcome	**O1**	**O2**	**O3**	**O4**	**O5**	**O6**	**O7**
Level of attainment	5	5	5	4	4	4	5

The expected levels of attainment for individual courses are given in Table 4 - 4 and are also set primarily by the instructors, in consultation with the Chair of the ABET Committee. The expected skill levels are somewhat subjective and different instructors will arrive at different levels. Note that CH EN 5230, Biosensors, and CH EN 5310, Renewable Energy, are fairly new technical electives for which skill levels have not yet been established.

Table 4 - 4. Expected Levels of Attainment for Outcomes 1 - 7 Using Skill Levels in Table 4 - 2, for Individual ChemE Courses

Course number	**Course Name**	**Outcomes and Skill Levels**						
		O1	**O2**	**O3**	**O4**	**O5**	**O6**	**O7**
1703	Intro to ChemE	3	2	1	3	2	5	3
1705	Design & Innov ChemE	6	6	6	3	3	6	6

2300	Thermo I	4	3	2	2	1	1	3
2450	Numerical Methods	5	2	4	2	2	5	4
2800	Process Engineering	4	4	3	2	3	3	3
3253	Chemical Process Safety	4	3	6	6	3	1	5
3255	Communication & Safety	2	3	6	5	4	2	2
3353	Fluid Mechanics	5	4	3	3	3	3	4
3453	Heat Transfer	5	4	4	3	3	4	4
3553	Reaction Engineering	5	5	4	2	3	4	2
3603	Mass Transfer & Separ	5	4	3	2	2	3	3
3853	ChemE Thermo	5	3	2	2	3	3	3
4203	Process Control	4	3	3	2	3	3	3
4253	Process Design I	5	6	5	6	3	4	6
4753/5	Seminar	1	1	3	4	1	1	5
4870	Industrial Energy Analysis	6	6	5	2	5	5	6
4903	Projects Lab I	6	5	6	6	6	6	6
4905	Projects Lab II	6	6	6	5	6	6	6
4977/8	Cooperative Education	3	3	4	3	3	3	2
5103	Biochem Engineering	5	5	2	4	3	3	4
5151	Combustion Engineering	5	3	3	3	3	2	3
5153	Fund of Combustion	5	5	4	3	3	3	3
5158	Energy and Society	5	3	4	4	3	4	3
5165	Midstream-Downstream	6	3	6	3	3	2	6
5205	Smart Systems	4	5	5	3	5	5	4
5207	Stats for ChemEs	5	4	4	3	2	5	3
5230	Bio-sensors							
5253	Process Design II	4	5	3	3	3	3	3
5305	Air Pollution Control Eng	5	4	3	3	2	4	4
5310	Renewable Energy							
5555	Catalysis	5	5	4	3	4	5	4
5810	Nanoscience	4	5	3	5	3	3	4

Results of the Evaluation Process and the Extent to Which Each Outcome Is Attained

Outcome 1

Outcome 1 states that by the time of graduation, students will have an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics. The data for the evaluation of the attainment of Outcome 1 consist of (1) assessments by ChemE instructors, (2) assessments by employers, (3) the results of the FE Examination, and (4) assessments by the director of the Engineering Math Program.

The assessment by ChemE instructors focuses on their experiences teaching the students in the 5 core, required, 4th-year courses and labs. Table 4-5 summarizes instructors' assessments for Outcome 1 based on data from Fall 2015 to Spring 2020. The values shown are averaged over that period and include multiple instructors. The expected level of attainment for Outcome 1 is 5, the assessed value is 4.8.

Table 4 - 5. Assessment by Instructors for Outcome 1

	Process Control 4203	Design I 4253	Design II 5253	Projects Lab I 4903	Projects Lab II 4905	Average
Expected	4	5	4	6	6	5
Assessed	4	5	3.4	5.6	6	4.8

The assessment by employers is made possible because students in Chemical Engineering can earn up to 6 units of technical elective credit through their co-op and internship experiences. Most students perform summer internships and these generally occur between the second and third, and third and fourth years. To be awarded credit, students must submit a report on the technical aspects of their experience and they must provide an evaluation by their supervisor. The evaluation asks employers to respond to 7 questions.

1. What technical skills does the student contribute to your organization?
2. What personal attributes does the student demonstrate, i.e. leadership, team player, organizational, work ethic, etc?
3. How well has this university education prepared the student to be successful?
4. If you were able to contribute suggestions regarding academic curriculum for students, what would they be?
5. Does the student understand the goal of the organization and their role in its success?
6. How does the student measure up to existing employee standards? If a job were available when the student graduates, would you offer a full-time position?
7. As an experienced professional in a field related to this student's area of study, you have valuable insight into what is required to be successful on the job. What advice would you give that would contribute to his/her preparation for a chosen career?

The Chair of the Undergraduate Committee tabulated the responses to questions 2, 3, and 4 and analyzed them for trends. Data from 90 internships were reviewed. The internships occurred from Summer 2015 to Spring 2020. To assess Outcome 1, the Chair focused on the employers' responses to question 3 since many students' success in an internship relates mainly to their university education and their ability to solve engineering problems by applying what they have learned in math, science, and engineering coursework. In virtually all cases, the employers report that the interns had good problem solving skills and were well prepared in the fundamentals. Several mention good critical thinking skills. One did gently note that the intern was still a sophomore and needed more training. However, several note that the interns need more practical experience with pumps and other process equipment in their third year coursework. Given that these observations are being applied to students in their second and third years, they provide ample evidence that Outcome 1 is being met at a skill level that is consistent with the findings of the instructors.

The percentage of ChemE students at the University of Utah and nationally who pass the FE Examination on their first attempt are summarized in Figure 2-1. There is one odd semester, Fall 2015. In that semester just 3 University of Utah students took the exam and only one passed. The average University and national passing rates over the 6 years in Figure 2 - 2 are 72 and 76 percent. When students do not pass the exam, their diagnostic reports show their performance, relative to national results. The FE covers the subjects of mathematics, probability and statistics, engineering sciences, computational tools, chemistry, fluid mechanics / dynamics, thermodynamics, material / energy balances, heat transfer, mass transfer and separations, chemical reaction engineering, process design and economics, process control, safety, health, and environment, and ethics and professional practice.

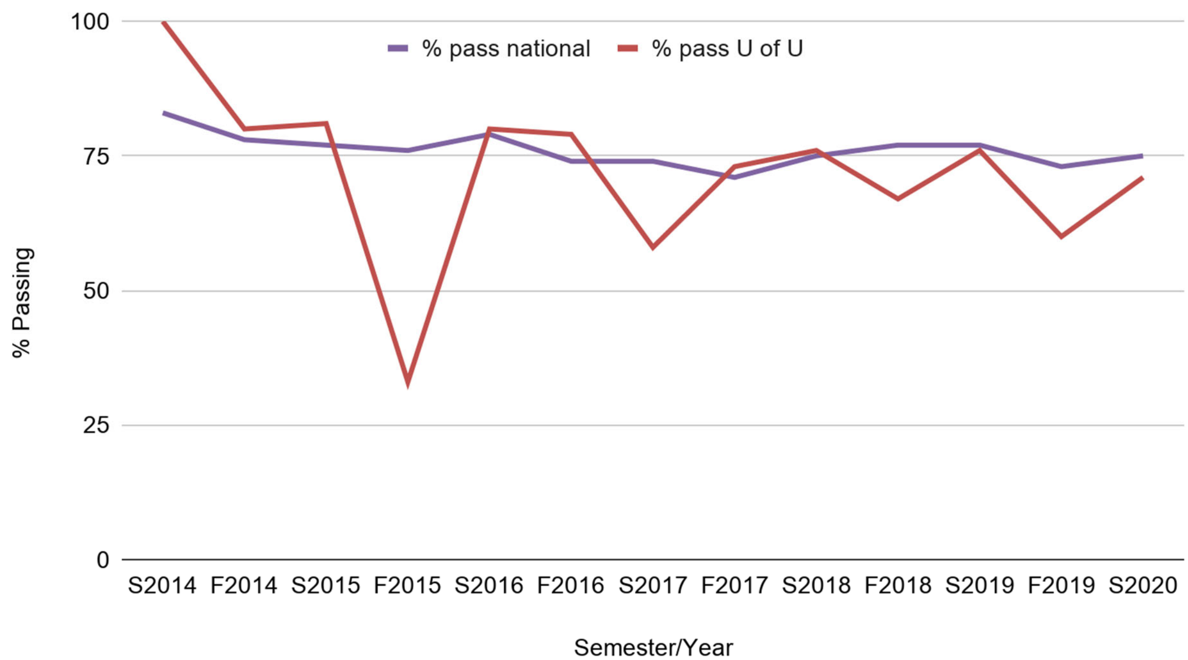

Figure 2 - 2. Percentage of ChemE Students, at the University of Utah and Nationally, Who Pass the FE (Chemical) Exam on Their First Attempt

Of those who don't pass, their diagnostic reports show broad weaknesses in many subject areas. We have not been able to identify specific subjects in the curriculum that need to be strengthened. The results of the FE show broad competency in the subjects of math, chemistry, physics and in the ability to apply those subjects to the solution of simple engineering problems. The results of the FE Exam provide additional evidence that Outcome 1 is being met at a skill level that is consistent with the findings of the instructors of the 4th year courses.

The Engineering Math Program started offering courses in Fall Semester 2012. The sequence was designed by faculty in Mathematics and Engineering with two goals: to provide a more streamlined presentation by deemphasizing proofs and to connect the mathematics to practical applications. The engineering sequence consists of four courses and is 16 units: MATH 1310 (Calc I), 1320 (Calc II), 2250 (LA and DE), and 3140 (Vector Calc and PDE). Up until the 2018-2019 Catalog Year, students in Chemical Engineering took the entire engineering sequence (see Table 0-1). MATH 3140 was dropped from our requirements in 2019-2020 to make room for CH EN 2550 (Statistics for ChemEs).

Professor Will Nesse in the Department of Mathematics is largely responsible for staffing, monitoring, improving, and assessing the Engineering Math Program. His data on pass rates by major in MATH 2250 (LA & DE) for Fall Semester 2017 are particularly revealing. The pass rates are 96.7% for BioE, 80.3% for ME, 78.9% for EE, and 61.5% for ChemE. The grade distribution for ChemE is distinctly bimodal, with plentiful A grades, not many B grades, and plentiful C's, D's, and E's. Prof. Nesse qualifies these results by noting that he does not distinguish between students with pre-major, intermediate, and major status. In Chemical

Engineering, intermediate status is used for students who have lost their major status due to academic difficulties. The pass-rate data may be skewed by this lack of discrimination. Bimodal grade distributions, however, tend to persist in subsequent ChemE courses, as noted by multiple instructors.

Finally, just a note on the complexity of the engineering problems that the students in our program are being asked to solve. Design I focuses on individual unit operations (heat exchangers, reactors, separators, etc.). For these complex designs, students primarily use Aspen Plus. Promax is also used, particularly for heat exchanger design. In Design II, students are required to combine individual unit operations into a complete plant design. The final project in Design II is the AIChE Design Competition problem.

The Projects Lab I (CH EN 4903) confronts students with open ended projects on larger pieces of equipment that sometimes do not work as expected. Project Lab II (CH EN 4905) is a capstone class in which students propose and complete projects that are generally quite complex. The complexity of the control schemes in Process Control (CH EN 4203) necessitates the use of Laplace transforms, Matlab or Python, and Simulink.

The 3rd-year courses are filled with complex engineering assignments. For example, (1) the students in Heat Transfer (CH EN 3453) design and analyze heat exchangers using Promax, (2) the students in Chemical Engineering Thermodynamics (CH EN 3853) use Aspen to analyze flash drums, (3) the students in Mass Transfer and Separations (CH EN 3603) use Python to analyze separation processes, and the students in Reaction Engineering (CH EN 3553) can use a variety of tools to analyze unsteady, nonisothermal reactors.

In conclusion, the data for the evaluation of the attainment of Outcome 1, show an acceptable level of achievement. The instructors for the core senior classes note expected and assessed levels of achievement of 5 and 4.8. The FE Exam shows that our students are performing close to the national average for their first attempt. The employers of interns and cooperative education students see their employees as being generally well prepared.

Outcome 2

Outcome 2 states that by the time of graduation, students will have an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors. The data for the evaluation of the attainment of Outcome 2 consist of (1) assessments by ChemE instructors, (2) assessments by employers, (3) the results of the FE Examination, (4) assessments by the Industrial Advisory Board, and (5) the Graduate Council Review.

The assessment by ChemE instructors focuses on their experiences teaching the 5 core, required, 4th-year courses and labs. Table 4-6 summarizes instructors' assessments for Outcome 2 based on data from Fall 2015 to Spring 2020. The values shown are averaged over that period and include multiple instructors. The expected level of attainment for Outcome 2 is 5, the assessed value is 4.5.

Table 4 - 6. Assessment by Instructors for Outcome 2

	Process Control 4203	Design I 4253	Design II 5253	Projects Lab I 4903	Projects Lab II 4905	Average
Expected	3	6	5	5	6	5
Assessed	3	5.75	3.5	4.55	5.88	4.54

One finding for Outcome 2 in Table 4 - 6 is disconcerting and that is the assessed skill level of 3.5 in Design II (CH EN 5253). In Design II, students are required to combine individual unit operations into a complete plant design. The final project is the AIChE Design Competition problem. The AIChE Design problem includes consideration of fixed capital investment; safety, health, and environmental concerns; process safety, manufacturing and operations costs, and economic analysis.

Design II is taught in spring and there were two instructors in the period from 2016 to 2020. Both made comments in their assessment reports. Prof. Whitty, who has taught the course just once, noted that the final reports were of poor quality, with a few notable exceptions. Prof. Ring noted that the students performed well in teams but that as individuals they were "hit and miss." Their low assessment of Outcome 2 is consistent with the highly variable performance of our students throughout our program.

Note that there is also a strong design component in Project Lab II (CH EN 4905). That lab is dedicated to a capstone project. Students propose projects, pitch them to the instructors and students, and then work in teams of three on those that are selected. Throughout the process, safety considerations are a major focus. Examples of recent projects include developing a device to prevent chest tube clogging, developing an ion exchange device to purify terbium, testing a corrosion inhibitor in a cooling tower, and making nitrogen-doped activated carbon for CO_2 capture. The assessment of 5.88 for Outcome 2 by the instructors of 4905 is encouraging.

Employers' evaluations of interns and co-op students for 90 students were analyzed. The evaluations occurred from Summer 2015 to Spring 2020. Recall that these observations are being applied to students in their second and third years of our program. In general, the evaluators are pleased with our students' preparation. Three employers in the oil and gas industry do, however, mention the need for more training in design. The supervisor at an oil refinery suggested that our curriculum provide more emphasis on "practical implementation of theoretical concepts used for equipment design, 3-dimensional thinking, and hands-on creative processes...." A second refinery manager comments that they would "like to see the students work more with pumps and control valves to size, design, and understand how they operate in tandem." A producer of oil and natural gas notes that almost no universities provide information on the design, manufacturing, and analysis of tanks, vessels, and piping systems.

The lack of additional employers' comments related to design suggests that Outcome 2 is being met at a skill level that is consistent with the level of preparation of the students, the findings of the instructors, and the needs of the employers.

The FE Exam includes the topic of process design and economics. However, the problems in this category focus primarily on simple process economics. The percentage of ChemE students at the University who pass the FE Examination on their first attempt is about 72%. Of those who don't pass, their diagnostic reports show broad weaknesses in many subject areas and we have not been able to identify process economics as a subject in the curriculum that needs to be strengthened. The results of the FE Exam suggest that the consideration of economic factors that is part of Outcome 2 is being met at a skill level that is consistent with the findings of the instructors of the 4th year courses.

A review of the minutes from the meetings of the Industrial Advisory Board shows that topics relating to Outcome 2 were discussed in 2015 April. The Board noted that having students build a device is a valuable design exercise because it teaches them how to bring a project together with a budget. The capstone project in CH EN 4905 is largely devoted to this goal.

In conclusion, the data for the evaluation of the attainment of Outcome 2 show an acceptable level of achievement but also raise some concerns. In particular, the instructors for Design II point to the uneven performance of our students and may indicate the need for a further tightening of academic standards. On average, the instructors for the core senior classes note expected and assessed levels of achievement of 5 and 4.54 for Outcome 2.

Outcome 3

Outcome 3 states that by the time of graduation, students will have an ability to communicate effectively with a range of audiences. The data for the evaluation of the attainment of Outcome 3 consist of (1) assessments by ChemE instructors, (2) assessments by employers, (3) the Senior Exit Interviews, and (4) assessments by the Industrial Advisory Board.

The assessment by ChemE instructors focuses on their experiences teaching the 5 core, required, 4th-year courses and labs. Table 4-7 summarizes instructors' assessments for Outcome 3 based on data from Fall 2015 to Spring 2020. The values shown are averaged over that period and include multiple instructors. The expected level of attainment for Outcome 3 is 4.6, the assessed value is 4.3.

Table 4 - 7. Assessment by Instructors for Outcome 3

	Process Control 4203	Design I 4253	Design II 5253	Projects Lab I 4903	Projects Lab II 4905	Average
Expected	3	5	3	6	6	4.6
Assessed	3	4.75	2.4	5.5	5.75	4.28

The communication component in Process Control (CH EN 4203) is limited to written communication and includes solutions to 11 homework assignments (submitted by individual students) and 4 projects (submitted by teams of 3). The team projects involve experimental work to design, build, and control the temperature of an electrical heater. The reports include (1) a statement of the problem, (2) a description of the solution strategy, (3) commented code (in appropriate), and (4) presentation and discussion of the results.

The communication component in Design I (CH EN 4253) is limited to written communication and includes 12 homework assignments and a project with a professional design report. The communication component in Design II (CH EN 5253) is limited to written communication and includes weekly design reports and a report on a comprehensive design project (group or individual assignment). The last is based on the AIChE Design Competition problem.

The communication component in the first projects lab, Projects Lab I (CH EN 4903), includes written and oral reports. The first written report is a formal report written as a team. Drafts of the introduction and theory sections are required from each individual student so that they can receive preliminary feedback prior to writing the team formal report. For the second and third reports, each individual student must write either a formal report or a memo report. If they choose to write a formal report first, then they write a memo report second, and so on. For all reports, students are encouraged to bring drafts to the instructors and TA for advice and to answer questions.

Beginning in Fall Semester 2019, in preparation for the capstone project in CH EN 4905, 4903 included a competitive proposal process in which each student writes a one-page proposal, creates a concept slide, and gives an oral pitch lasting from 2.5 to 3.5 minutes. Prior to Fall Semester 2019, the pitch was part of 4905. The proposed capstone project is to address one or more of the following goals: (1) solve a chemical engineering problem for a company, (2) pursue a research problem within a department, (3) improve the capabilities of a teaching laboratory, and (4) advance the service or teaching missions of the department (outreach or community service projects).

The communication component in the second, capstone projects lab, Projects Lab II (CH EN 4905), includes (1) a group proposal, (2) a final group formal report, and (3) a poster presentation at a symposium. Before Items 1 and 2, each team schedules an oral meeting with their professor to review their project's safety, planning, and theory. A job hazard analysis (JHA) is submitted at each meeting.

The assessment of Outcome 3 by the instructors of the 4th year classes, as outlined in Table 4 - 7, is based on extensive written and oral work from individual students and from teams. The expected level of attainment for Outcome 3 is 4.6, the assessed value is 4.3.

Employers' evaluations of interns and co-op students for 90 students were analyzed to assess their communication skills. The evaluations occurred from Summer 2015 to Spring 2020. Recall that these observations are being applied to students in their second and third years of our program. Fourteen employers made comments about the interns' communication skills.

Regarding communication and our curriculum, one employer pointed out the importance of being able to adjust presentations for those who are not technically proficient. A second reiterated the need for additional writing and communication classes across all industries. Regarding the preparation the interns received at the University of Utah, one noted that we should focus more of our attention on communication and collaborative work.

The remaining 11 comments are laudatory and include several that refer to the interns' ability to communicate with diverse groups. For example, regarding interns' personal attributes, typical comments include (1) good communication with diverse employees and personality types, (2) he demonstrates superior communication skills and works to truly understand someone's opinions and needs, (3) she was able to communicate with people of various technical backgrounds, (4) she is a team player with great communication skills, (5) excellent communication skills, (6) good communication skills, (7) good communication skills on a multi-functional team.

The Chair, Associate Chair, and Academic Adviser conduct Senior Exit Interviews in April and May with groups of about 10 students. The students are asked to respond to 4 broad questions regarding

- Post graduation plans
- Teaching and learning
- Adequacy of classrooms, study space, software, and labs
- Social, emotional, and cultural environment

Meeting with groups of students, whether in person or online, promotes more interaction and exchange of ideas. Minutes are prepared each year and distributed to faculty and staff. Their comments about communication are summarized below for 2016 - 2020.

- 2016 - The seniors felt well prepared in their ability to communicate but expressed the need for more training in oral communication.
- 2017 - The seniors primarily mentioned the writing and speaking practice they received in the projects lab and they felt that they had enough practice. Several mention the helpfulness of Prof. Sutherland's requiring them to type up and explain their homework solutions in CH EN 3603, Mass Transfer and Separations. Some wish they had more practice in oral communication.
- 2018 - The seniors did not find our one-credit communication course helpful. They asked for more feedback on their writing. No other comments were submitted regarding communication.
- 2019 - The one-credit writing course was heavily criticized because it does not provide adequate feedback, does not provide an opportunity to revise your writing, should be earlier in the program (it was in the 2nd semester of the third year), and places too much emphasis on quizzes and not enough practice on writing.
- 2020 - The seniors knew of our plans to introduce a technical writing course in the first semester of the third year and thought that it was good to have it earlier in the curriculum.

In general, the exit interviews reveal that the seniors feel they receive adequate preparation to communicate effectively. The lack of comments regarding oral communication in 2018-2020 suggests that that concern no longer exists.

The Chemical Engineering Industrial Advisory Board (IAB) meets once per year. Some of the members participate in interviewing workshops involving our undergraduates. Some also recruit our students for internships and full time positions. The following summary relates to their experiences giving interviews and is a good indication of students' ability to communicate orally in a stressful situation.

In our 2015 meeting, the President of Gap Engineering noted that our younger students have a hard time talking about whether they would fit with company culture and values. He noted that our older students tend to do better in interviews. He and others urged us to give students practice interviewing early in the program.

In our 2016 meeting, the President of Gap Engineering again remarked that our students really struggle with interviews. He said that his strategy in interviewing is to discover someone's core values. He knows that some students who interviewed poorly would have made good engineers.

At the 2018 meeting, the Department introduced the changes it was making to the undergraduate seminar to have it focus on improving job interviewing skills and the preparation of resumes and cover letters. The IAB was pleased with these changes.

In conclusion, the data for the evaluation of the attainment of Outcome 3 show an acceptable skill level. On average, the instructors for the core senior classes note expected and assessed levels of achievement of 4.6 and 4.3 for Outcome 3. The effects of adjusting the undergraduate seminar to focus on improving interviewing skills is still being evaluated.

Outcome 4

Outcome 4 states that by the time of graduation, students will have an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts. The data for the evaluation of the attainment of Outcome 4 consist of (1) assessments by ChemE instructors, (2) assessments by employers, (3) the FE Exam, and (4) Senior Exit Interviews.

The assessment by ChemE instructors focuses on their experiences teaching the 5 core, required, 4th-year courses and labs. Table 4-8 summarizes instructors' assessments for Outcome 4 based on data from Fall 2015 to Spring 2020. The values shown are averaged over that period and include multiple instructors. The expected level of attainment for Outcome 4 is 4.4, the assessed value is 4.36.

Table 4 - 8. Assessment by Instructors for Outcome 4

	Process Control 4203	Design I 4253	Design II 5253	Projects Lab I 4903	Projects Lab II 4905	Average
Expected	2	6	3	6	5	4.4
Assessed	2	6	2.8	6	5	4.36

The syllabus for Process Control (CH EN 4203) provides guidelines regarding professional behavior and academic ethics. These include doing your share on a team, not disrupting lectures, and acting to increase your scores by means other than increasing your knowledge. The syllabus for Design I (CH EN 4253) provides guidance regarding academic misconduct. The evaluation of overall plant economics is necessarily part of both design courses. The syllabus for Design II (CH EN 5253) requires students to be able to independently set up, solve, and explain solutions to all problems. The learning outcomes in the syllabus for Projects Lab I (CH EN 4903) enjoin students to apply professional ethics to design and conduct experiments, and to analyze and interpret the results. The learning outcomes in the syllabus for Projects Lab II (CH EN 4905) mirror those for 4903.

Employers' evaluations of interns and co-op students for 90 students were analyzed to assess their professionalism and ethical behavior. Item 2 of the employers' evaluations looks at personal attributes such as leadership, organizational ability, and work ethic. In general, the responses are favorable with many employees commenting on the interns' strong work ethic, awareness of safety, initiative, organizational skills, resourcefulness, leadership skills, ability to work with little supervision, and positive attitudes.

The FE Exam includes problems on safety, health, environment, and ethics and professional practice. Our students generally do well in these subjects.

The senior exit interviews include a question on the social and cultural environment in the department. The seniors are generally positive about the program, stating that faculty, staff, and students are helpful and respectful of each other. Some students in the Class of 2019 raised ethical concerns about the existence of two Google drives. One drive had reference materials such as textbooks, solution manuals, and handbooks. The other included solutions to previous homework assignments and exams. Several students noted that only a clique had access to these. The students who did not have access to the old exams and homework asked that instructors make their old exams available to all students. Most faculty members have subsequently done so and the seniors in their 2020 exit interviews did not mention the Google drives as a concern.

In conclusion, the data provided by the instructors, employers, FE Exam, and senior exit interviews show that our students are able to practice Outcome 4 with an acceptable skill level. On average, the instructors for the core senior classes note expected and assessed levels of achievement of 4.4 and 4.4 for Outcome 4.

Outcome 5

Outcome 5 states that by the time of graduation, students will have an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives. The data for the evaluation of the attainment of Outcome 5 consist of (1) assessments by ChemE instructors, (2) assessments by employers, and (3) Senior Exit Interviews.

The assessment by ChemE instructors focuses on their experiences teaching the 5 core, required, 4th-year courses and labs. Table 4-9 summarizes instructors' assessments for Outcome 5 based on data from Fall 2015 to Spring 2020. The values shown are averaged over that period and include multiple instructors. The expected level of attainment for Outcome 5 is 4.2, the assessed value is 4.5.

Table 4 - 9. Assessment by Instructors for Outcome 5

	Process Control 4203	Design I 4253	Design II 5253	Projects Lab I 4903	Projects Lab II 4905	Average
Expected	3	3	3	6	6	4.2
Assessed	3	4.67	3.1	5.93	6	4.47

The 5 courses highlighted in Table 4 - 9, with the exception of Design I, make extensive use of teamwork. Process Control involves four group lab projects worth 20 percent of the grade. Design II includes a group or individual final team project, the AIChE Design Problem, that is counted 50 percent of the grade. Almost all of the students in Design II chose to work in teams of 3 on the projects. The Projects Labs involve extensive teamwork. Fifty percent of the grade in Lab I is based on group assignments and 80 percent in Lab II.

Employers' evaluations of interns and co-op students for 90 students were analyzed to assess their ability to function effectively on a team. Item 2 of the employers' evaluations looks at personal attributes and includes the ability to work on a team. About 55 of the 90 supervisors specifically mention good teamwork skills. Two specifically mention the ability to work with cross-functional groups or multi-disciplined teams. Other typical comments include, consummate team player, great team player, worked well with every member of our small team, excellent teamwork with peers and operators, committed to the team, and fit in with our team immediately.

The senior exit interviews generally include favorable comments regarding teamwork. Typical comments are that they loved the teamwork and that it was good to have assigned teams even though some of their teammates don't carry their fair share of the work. Most of the interviews include positive comments about the ChemE computing space, the Industrial Computing Center (ICC). They say that the ICC helps build community, provides a place for getting help, and is good for group work. Most of the seniors point to the need for more study space with whiteboards. This is a strong indication of their desire to work in teams.

In conclusion, the assessments of the instructors, employers, and students show that our students are able to function effectively on teams and satisfy Outcome 5. On average, the instructors for the core senior classes note expected and assessed levels of achievement of 4.2 and 4.5 for Outcome 5.

Outcome 6

Outcome 6 states that by the time of graduation, students will have an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions. The data for the evaluation of the attainment of Outcome 6 consist of (1) assessments by ChemE instructors and (2) assessments by employers.

The assessment by ChemE instructors focuses on their experiences teaching the 5 core, required, 4th-year courses and labs. Table 4-10 summarizes instructors' assessments for Outcome 6 based on data from Fall 2015 to Spring 2020. The values shown are averaged over that period and include multiple instructors. The expected level of attainment for Outcome 6 is 4.4, the assessed value is 4.13.

Table 4 - 10. Assessment by Instructors for Outcome 6

	Process Control 4203	Design I 4253	Design II 5253	Projects Lab I 4903	Projects Lab II 4905	Average
Expected	3	4	3	6	6	4.4
Assessed	3	4	2.25	5.79	6	4.13

The 5 courses highlighted in Table 4 - 10 involve either the analysis of data, the development and performance of experiments, or both. Process Control involves four group lab projects worth 20 percent of the grade. The projects involve instrumenting a process, performing process identification, designing a controller, and demonstrating its performance.

Design I does not involve any experimental work but does include the analysis and application of experimental data for designing unit operations and for their economic analysis. Design II has similar characteristics but the data are applied to the design of entire processes.

The projects labs involve extensive experimentation, analysis of data, and writing of reports that draw conclusions. Three projects are assigned in Lab I. The projects apply concepts from heat transfer, fluid mechanics, separations, reaction engineering, and thermodynamics. Lab II involves a single capstone project. The learning outcomes for Lab I that directly relate to Outcome 6 include

- Apply concepts from mathematics to model and analyze the performance of unit operations
- Perform statistical analysis of data include computing confidence intervals
- Develop experimental objectives to meet overall project objectives
- Design and conduct experiments to meet overall experimental goals
- Analyze experimental data to obtain parameters and correlations describing the performance of process equipment
- Evaluate the quality of experimental results by comparison with accepted correlations and theory
- Explain deviations from expected behavior.

The learning outcomes for Lab II are similar but the teams focus on a single capstone project that addresses one or more of the following goals; (1) solve a chemical engineering problem for a company, (2) pursue a research problem within a department, (3) improve the capabilities of a teaching laboratory, and (4) advance the service or teaching missions of the department (outreach or community service projects). The projects almost always involve physical experiments although simulations may replace or supplement the experiments.

Employers' evaluations of interns and co-op students for 90 students were analyzed to assess their ability to develop and conduct experiments and analyze and interpret data. The evaluations show generally positive results for Outcome 6 even though the interns have not taken the projects labs. Of the 15 evaluations that mention laboratory work or experience, 9 are positive. Three suggested that more lab experience would be helpful and two recommended that students be exposed to more design of experiments. Four additional employers mentioned the need for more experience with equipment design, specification, and troubleshooting. Keep in mind that most students perform their internships between the 2nd and 3rd or 3rd and 4th years, before they have taken the senior projects lab courses, CH EN 4903 and 4905.

Beginning Fall Semester 2020, the Department is phasing in a new lab structure that seeks to better integrate the 3rd-year courses with laboratory experiences. The existing lab structure includes 3 units in the first year (CH EN 1705) and 7 units in the fourth year (CH EN 4903, 4905). The new structure includes 3 units in the first year (CH EN 1705), 4 units in the 3rd year (CH EN 3701, 3702), and 5 units in the 4th year (CH EN 4701, 4706, 4707). CH EN 4701 is one unit and focuses on process control. CH EN 4706 and 4707 are a capstone project. Additional information on these changes is included in the next section, B. Continuous Improvement.

In conclusion, the data for the evaluation of the attainment of Outcome 6 show an acceptable skill level. On average, the instructors for the core senior classes note expected and assessed levels of achievement of 4.4 and 4.1 for Outcome 6. The effects of adjusting the structure of the labs will be evaluated over the coming years.

Outcome 7

Outcome 7 states that by the time of graduation, students will have an ability to acquire and apply new knowledge as needed, using appropriate learning strategies. The data for the evaluation of the attainment of Outcome 7 consist of (1) assessments by ChemE instructors, (2) assessments by employers, and (3) the senior exit interviews.

The assessment by ChemE instructors focuses on their experiences teaching the 5 core, required, 4th-year courses and labs. Table 4-11 summarizes instructors' assessments for Outcome 7 based on data from Fall 2015 to Spring 2020. The values shown are averaged over that period and include multiple instructors. The expected level of attainment for Outcome 7 is 4.8, the assessed value is 4.63.

Table 4 - 11. Assessment by Instructors for Outcome 7

	Process Control 4203	Design I 4253	Design II 5253	Projects Lab I 4903	Projects Lab II 4905	Average
Expected	3	6	3	6	6	4.8
Assessed	3	6	2.60	5.67	6	4.63

The 5 courses highlighted in Table 4 - 11 strongly depend on the need for students to acquire and apply new knowledge. This is because they involve open ended assignments that require lab and design work. Process Control involves four group lab projects worth 20 percent of the grade. The projects involve instrumenting a process, performing process identification, designing a controller, and demonstrating its performance. Design I focuses on the design of individual unit operations (heat exchangers, reactors, separators, etc.). In Design II, students are required to combine individual unit operations into a complete plant design. The final project for Design II is the AIChE Design Competition problem. The Projects Lab I (CH EN 4903) assigns students open ended projects on larger pieces of equipment that sometimes do not work as expected. Project Lab II (CH EN 4905) is a capstone class in which students propose and complete projects that address one or more of the following; (1) solve a chemical engineering problem for a company, (2) pursue a research problem within a department, (3) improve the capabilities of a teaching laboratory, and (4) advance the service or teaching missions of the department (outreach or community service projects).

Employers' evaluations of interns and co-op students for 90 students were analyzed to assess their ability to acquire and apply new knowledge. One employer suggested that our curriculum should do more to expose students to various resources (books, internet, etc.) as part of their assignments. About 30 employers, however, commented favorably regarding the interns ability to learn. Typical comments include, he is a quick learner, he is able to learn new chemical reactions, he is always open to learning new things, she was able to learn what was needed without delay, and she dug in and learned what was needed for the position.

The senior exit interviews show compelling evidence that the students learn from each other. One of the most common comments in the interviews is regarding the importance of our student computing lab (the ICC or Industrial Computing Center). It is a place where students go to work together, learn from each other, and seek help from other students. One of the most common requests that the seniors make in the interviews is for more study space.

In conclusion, the open-ended nature of the courses in the senior year requires that students strengthen their ability to acquire and apply new knowledge before they graduate. The evaluation by instructors for the achievement of Outcome 7 are quite positive; the expected and observed levels of attainment are 4.8 and 4.6. The employers of our interns are also quite positive about their ability to learn.

Outcomes Conclusions

Table 4-12 provides a summary of the expected and observed skill levels for Outcomes 1 - 7. The assessments were performed by the instructors for the required, 4th-year courses in Chemical Engineering. The instructors' assessments are supported by several other assessment tools: the results of the Fundamentals of Engineering Exam, evaluations by employers of interns and co-op students, our industrial advisory board, the senior exit interviews, and the graduate council review. Overall, these tools support the findings in Table 4 - 12.

Table 4 - 12. Summary of Expected and Observed Levels of Achievement for Outcomes 1 - 7

	Outcome 1	**Outcome 2**	**Outcome 3**	**Outcome 4**	**Outcome 5**	**Outcome 6**	**Outcome 7**
Expected	5	5	5	4	4	4	5
Assessed	4.8	4.5	4.3	4.4	5	4.1	4.6

A. Continuous Improvement

Describe how the results of evaluation processes for the student outcomes and any other available information have been systematically used as input in the continuous improvement of the program. Describe the results of any changes (whether or not effective) in those cases where re-assessment of the results has been completed. Indicate any significant future program improvement plans based upon recent evaluations. Provide a brief rationale for each of these planned changes.

The process for continuous improvement of the Chemical Engineering Program is sketched in Figure 4 - 1. This process has led to significant changes in the program since our last general review in 2015-2016. Those changes, and the catalog year associated with them, are summarized in Table 0 - 1. Included with each change are justifications for the changes. The ways in which the evaluation process for the student outcomes have been used to motivate the changes in Table 0-1 are summarized below.

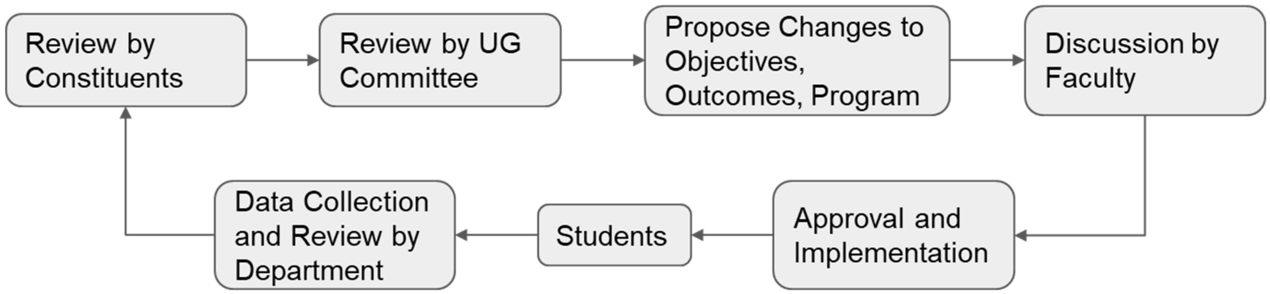

Figure 4 – 1. Process for Improvement of the Undergraduate Program

Assessment by Chemical Engineering Instructors

The assessments of the learning outcomes by the instructors show that the expected outcomes are generally being met across the curriculum. There is one course, CH EN 5253, Design II, however, that has shown fairly consistent weaknesses in most of the outcomes. Design II is a capstone class that draws upon everything the students have learned and weaknesses in this course are of concern. The instructor notes that the students perform well in teams, but as individuals they are, in a few cases, not able to do so. The same instructor has noted similar weaknesses in CH EN 4903, Project Lab I, and has repeatedly reported that the students in 4903, at least in the section he taught, have not mastered anything. The instructor of the other section of 4903 has observed acceptable skill levels. More data is needed to increase confidence in these findings. No changes have been made to the curriculum or program in response to these findings.

Senior Exit Interviews

The feedback from seniors has resulted in several changes to our curriculum to address the following.

For several years the seniors have pleaded for alternatives to CHEM 3060, Quantum Chemistry. Students can now choose between CHEM 3060, MSE 3210, Electronic Properties of Solid, and ECE 3200, Semiconductor Device Physics. Complaints have ceased since this change was made and it provides students with the opportunity to learn more about semiconductors. This is significant because the semiconductor industry hires many of our graduates.

The seniors noted that employers are seeking candidates with more background in statistics and data science. A sophomore-level class is now required: CH EN 2550, Statistics for Chemical Engineers. A popular, senior-level technical elective, CH EN 5205, Smart Systems, introduces real-time optimization and machine learning with neural networks. Smart systems was first taught in Spring Semester 2017 and has been offered every year since then.

The seniors noted that employers are seeking candidates with more programming experience. The curriculum has been restructured so that the first four semesters of the major involve courses that require programming. These courses are CH EN 1703 (Introduction to Chemical Engineering), CH EN1705 (Design and Innovation in Chemical Engineering), CH EN 2550 (Statistics for Chemical Engineers), and CH EN 2450 (Numerical Methods).

The seniors suggested restructuring the UG seminar to focus on preparing students for graduate school or finding employment. We have implemented that change and have reduced the number of required semesters of seminar from 4 to 2.

The seniors complained that the junior year was too abstract and theoretical. Junior-level labs have been added to provide hands-on learning experiences in heat transfer, fluid mechanics, equilibrium thermodynamics, reaction engineering, mass transfer and separations, and biochemical engineering. The first of these labs, CH EN 3701, will be offered for the first time Fall Semester 2020. The second, CH EN 3702, will be offered Spring Semester 2021. The third, CH EN 4701, will be offered Fall Semester 2021.

Evaluations of Co-op Students and Interns by Employers

Students in Chemical Engineering can earn up to 6 units of technical elective credit through their co-op and internship experiences. To be awarded credit, students must submit a report on the technical aspects of their experience and they must provide an evaluation by their supervisor. Employers have made the following suggestions to improve the curriculum.

The most common suggestion is to expose students to more statistics and data science, including design of experiments and data visualization. The Department has added a required statistics course in the third semester of the program, CH EN 2550, Statistics for Chemical Engineers, to address this need. Students may also substitute two other courses for 2550: ME EN 2550 (Applied Probability and Statistics for Engineers) and MATH 3070 (Applied Statistics I).

Another common suggestion is to provide more hands-on experiences, that is, laboratory work. The department has added labs to the junior year, CH EN 3701 and 3702, Projects Labs I & II, that will be held for the first time Fall Semester 2020.

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A third common suggestion is to put more emphasis on specifying equipment such as pumps, heat exchangers, flow meters, relief valves, pressure vessels, tanks, piping, etc. The Department has added a heat exchanger design project to the junior year that uses ProMax Process Simulation Software. The Department needs to work toward developing more assignments related to specification of equipment in the junior year. The senior design sequence, CH EN 4253, 5253, provides extensive design experience but the employers of interns don't see the results of that because almost all internships occur before the senior year.

Feedback from FE Exam

Up until Fall Semester 2020, the Department required that students take the Fundamentals of Engineering (FE) (Chemical) Exam. If students did not pass on their first attempt, a second was required. Roughly 72% of our students passed the FE exam on their first attempt. This rate is comparable to the national average of 76%. Of those who didn't pass, their diagnostic reports were provided to them and they were required to provide the reports to the Department. The reports show broad weaknesses in many subject areas. Based on the FE Exam, we have not been able to identify specific subjects in the curriculum that need to be strengthened.

Feedback from Industrial Advisory Board

The Industrial Advisory Board (IAB) meets once a year and concludes with an alumni dinner. Many of the members of the IAB are alumni. The industries represented include semiconductor, medical devices, personal and family care products, engineering design and construction, pharmaceutics, food, mining and mineral processing, and oil and gas.

In their 2015 and 2016 meetings, the IAB stressed the importance of giving students more practice at interviewing earlier in our program. In response, the Department restructured the UG Seminar in 2018-2019 to focus more on developing interviewing and resume writing skills, with seminar speakers from industry and the University's Career Center.

The 2016 meeting stressed the importance of data science. The semiconductor industry uses data science extensively and one of their representatives defined its three essential components as (1) computing, (2) statistics, and (3) knowledge of the physical process being studied. The Department has responded to this by developing a new, required statistics course, CH EN 2550, Statistics for Chemical Engineers. It uses examples from environmental problem solving, the semiconductor industry, reaction engineering, and epidemiology. This course was initially made available as an elective, CH EN 5702/6702 (Statistics for Chemical Engineers). It was added as a required course for the 2019-2020 catalog. It was subsequently moved to the first semester of the second year and renumbered to CH EN 2550.

In the 2017 meeting, data science was again a topic of discussion with mention of the importance of being able to analyze large data sets and the importance of being able to write code to analyze big data sets.

The 2018 meeting reviewed the progress we are making in reshaping our curriculum. We received a positive response. The IAB in their 2019 meeting reminded the department of the importance of life skills, project management, and concluded that our new two-semester capstone project could facilitate interdisciplinary work with computer science, mechanical engineering, and electrical engineering. The department had previously decided to extend the capstone project over two semesters to allow more time for completion of the projects and for interdisciplinary work.

Input from Visitors

The Department regularly hosts visitors as part of its Distinguished Lecture Series, and sometimes as part of its research activities or alumni relations. These visits usually include a round-table lunch and discussion with the faculty followed by an afternoon seminar. The round-table lunches frequently involve discussions of curriculum and teaching that allow us to compare what we are doing with other programs.

For example, Prof. Richard Braatz (Chemical Engineering, MIT) visited in September 2017, and noted that statistics is neglected in most UG and graduate curricula. Peter Meldrum, founder of Myriad Genetics, visited in March 2017 and pointed out that one of his most valuable UG courses was on writing and grammar. Rick Russell, President of Merit Sensor, visited in March 2017 and noted that applicants to his company for process engineering positions need statistical process control and the ability to program. He said he would welcome any job applicant with a background in programming.

We have long considered the desirability of offering our required courses twice per year. Prof. Ted Randolf (Chemical Engineering, U of Colorado) visited in October 2018 and discussed the problems they are having with two offerings per year: (1) students who failed the first offering are concentrated in the second offering, and (2) students are selecting the path of least resistance by choosing instructors who are perceived to be “easier”.

Prof. Gretar Tryggvason (Mechanical Engineering, John Hopkins) visited February 2020 and noted that we all agree that students should be able to program. He went on to say that a continuing challenge is getting the faculty who teach classes to exercise the programming skills of their students. This challenge persists to a limited extent in our program. The first four semesters include four computationally intensive Chemical Engineering courses (1703, 1705, 2550, 2450) and the junior year includes at least three (3453 Heat Transfer, 3603 Mass Transfer and Separations, and 3553 Chemical Reaction Engineering).

In conclusion, our assessment procedures and feedback loop provide a way to adapt, strengthen, and modernize our curriculum. As changes are made, we continue to collect data and assess outcomes, all with the goal of helping our students meet our educational objectives.

Planned Changes to Chemical Engineering Program

Extensive changes to the structure of our labs are being phased in during 2020-2021 Catalog year. The changes are designed to better integrate the core chemical engineering courses in the third year, with hands-on, laboratory experiences. Table 4-13 shows years 3 and 4 of the current, 2019-2020 Program of Study. In the 2019-2020 Program, the projects labs (CH EN 4903, 5) are in the senior year and total 7 credit hours. Table 4-14 shows years 3 and 4 of the 2020-2021 Program of Study. In the 2020-2021 Program, there are 4 credit hours of lab work in year 3 (3701, 2) and these are designed to complement the core curriculum: CH EN 3353, 3453, 3853, 3553, 3603, and 5103. In year 4 there are 5 credit hours of laboratory work. These include a capstone sequence, CH EN 4706, 7, and a one-credit lab (4701) designed to complement the Process Control class, 4203.

There is one additional change of note in the 2020-2021 Program: the one-credit communication course (CH EN 3255), has been moved to the first semester of the 3rd year and has been changed to a 3-credit class. Its new number is CH EN 3700. This course is designed to complement and strengthen communications skills in conjunction with the 3rd year labs.

Table 4 - 13 2019-2020 Program of Study for Years 3 and 4 of Chemical Engineering

THIRD YEAR			
Fall Semester	Units	**Spring Semester**	Units
Technical Elective	3	CH EN 3253 Chemical Process Safety	3

CH EN 3353 Fluid Mechanics	3	CH EN 3255 Communication & Safety	1
CH EN 3453 Heat Transfer	3	CH EN 3603 Mass Transfer, Separations	3
CH EN 3853 Chemical Eng Thermo	3	CH EN 3553 Chemical Reaction Eng	3
CH EN 5207 Stats for ChemE	3	CH EN 5103 Biochemical Engineering	3
		General Education/Bachelor Req	3
Total	15	Total	16
FOURTH YEAR			
Fall Semester	Units	**Spring Semester**	Units
CH EN 4903 Projects Laboratory I	4	CH EN 4905 Projects Laboratory II	3
CH EN 4253 Process Design I	3	CH EN 5253 Process Design II	3
CH EN 4203 Process Control	3	Technical Elective	6
Technical Elective	3		
General Education/Bachelor Req	3		
Total	16	Total	12

Table 4 - 14 2020-2021 Program of Study for Years 3 and 4 of Chemical Engineering

THIRD YEAR				
Fall Semester	Units		**Spring Semester**	Units
CH EN 3353 Fluid Mechanics	3		CH EN 3603 Mass Transfer, Separations	3
CH EN 3453 Heat Transfer	3		CH EN 3553 Chemical Reaction Eng	3
CH EN 3853 Chemical Eng Thermo	3		CH EN 5103 Biochemical Engineering	3
CH EN 3700 Technical Communication	3		CH EN 3702 Projects Lab II	2
CH EN 3701 Projects Lab I	2		General Education/Bachelor Req	3
Total	14		Total	14
FOURTH YEAR				
Fall Semester	Units		**Spring Semester**	Units
CH EN 4701 Projects Lab III	1		CH EN 4707 Capstone Project II	2

CH EN 4706 Capstone Project I	2		CH EN 5253 Process Design II	3
CH EN 4253 Process Design I	3		CH EN 3253 Chemical Process Safety	3
CH EN 4203 Process Control	3		Technical elective	3
Technical Electives	6		General Education/Bachelor Req	3
Total	15		Total	14

The decision to end the requirement that graduating students take the FE Exam was reached in Fall Semester 2020 and was based on several factors.

- There was no evidence that the exam was being used to improve our teaching.
- A national survey of chemical engineering programs in the United States showed that just 4 of 55 respondents were requiring some form of final, comprehensive exam. Two of those 4 were required by their institutions to have a final, comprehensive exam. Three of the four used the FE as that exam.
- The exam is expensive ($175) and we asked students to pay for it.
- Only one or two of the companies or governmental agencies that regularly hire our students require that their employees take and pass the exam.

The Undergraduate Committee debated whether to develop our own comprehensive exam and ultimately decided against doing so. The key factors that helped us reach that decision were (1) that is it not clear how the exam would benefit our teaching, (2) that it would take considerable faculty time, and (3) that it would greatly add to the stress that seniors feel while they are taking difficult courses and looking for employment. The Undergraduate Committee agreed that language should be added to the UG Handbook that encourages students to take the FE Exam if they know that their potential employers require it.The faculty voted in favor of ending the exam requirement in the 2020 November faculty meeting.

Several members of the UG Committee proposed, however, that instructors might take a suggestion from Richard Felder and give low stakes exams (maybe 5% of the total points) that test their students' grasp of prerequisites at the beginning of the semester. Tony Butterfield thought the Capstone Lab would be a good place to give such an exam and Milind suggested that he would give the same or similar exam in Design II. The results of such testing have the potential to achieve some of the assessment of outcomes that has been provided by the FE Exam.

The department will continue to gather data and assess and evaluate the effect of these changes on the achievement of the outcomes.