Summary of ABET Student Outcomes Assessment, 2019-2020

Bachelor of Science in Chemical Engineering

Chemical and Biomolecular Engineering Department

University of California, Berkeley

July 1, 2020

Executive Summary

This report presents the direct and indirect student outcomes assessment data collected from instructors and students during the 2019-2020 academic year. It is intended for use in department-level curricular continuous improvement efforts, and creates a record for current and future ABET program evaluators and decision makers.

This report follows the approach outlined in the Process: Assessing and Evaluating Attainment of Student Outcomes document adopted January 4, 2013. Part 1 reports the direct measures results by first reviewing the process and then presenting data sampled from the course Outcome Assessment Templates during the 2019-2020 academic year. Part 2 reports the indirect measures results by first reviewing the process and then presenting data from the spring 2020 graduating senior survey, and the 2019-2020 student focus groups (AIChE Student-Faculty Focus Group and Honors Student Tea). Part 3 summarizes the responses and outcomes from the 2018-2019 cycle.

Direct measures from student classwork show very good achievement of almost all outcomes during the 2019-2020 year. Only **Outcome 1** (identify, formulate, and solve complex engineering problems) has a measure in the "yellow" zone: a single instance from 150B with a 72% pass rate. This is nearly at the "yellow-green" borderline of 75%, and not past the action threshold, but is worth some discussion by faculty. Survey and/or focus group responses show that students continue to be confident about their skills and abilities in most Student Outcomes, especially **Outcome 1** (apply math, science, engineering), **Outcome 5** (teamwork), and **Outcome 6** (design, analyze, interpret experiments). They suggest some focus on improvement in **Outcome 2** (apply engineering design to produce solutions that meet specified needs). Students recommend discussion on continued integration of communications (**Outcome 3**), and ethics (**Outcome 4)** across the curriculum.

As a note of context, Dr. Shannon Ciston, who oversaw our ABET process for many years, left UC Berkeley as of April 1, 2020. Professor Susan Muller assumed responsibility for ABET as of that date. In

addition, due to public safety orders related to COVID-19, all instruction shifted to online-only on March 17, 2020. As a result, student focus groups and the senior survey were conducted virtually, and under less than ideal conditions.

Part 1: Direct Measures: Student Course Work

Process excerpt:

a. *Each Student Outcome is assessed in at least two core chemical engineering courses that apply the Outcome to a high degree.*
    i. *See Student Outcome-Course Matrix for mapping.*
    ii. *For each Outcome, core courses are chosen from different levels of the curriculum (such as sophomore and senior) so that the development of each Student Outcome may be monitored over time.*
    iii. *Each core course in the curriculum is used to assess at least one Student Outcomes.*

b. *Faculty and graduate student instructors of each course assess student course work and use the course Outcome Assessment Template to report the number of students who fail, pass, or pass with distinction each of the Student Outcomes.*
    i. *Outcome Assessment Templates are also used for course-level outcome assessment.*
    ii. *When a course-level outcome is highly similar to the given Student Outcome, the same measure is used for both.*
    iii. *See Outcome Assessment Templates for Student Outcomes for details.*
    iv. *Outcome Assessment Templates are collected each semester by instructor submission to a specified site in the Berkeley online course management system, administered by the department ABET coordinator.*

c. *In June of each year, the ABET coordinator generates a Quantitative Student Outcome Attainment report using the data from the Outcome Assessment Templates.*
    i. *For each Student Outcome, the lower level course is analyzed in odd calendar years, and the higher level course is analyzed in even calendar years. For example, Student Outcome 2 is analyzed in 40 (freshman) in 2019 and in 160 (senior) in 2020.*
    ii. *The Outcome Assessment Template data are used to calculate a percentage pass rate for each Student Outcome.*
    iii. *Trends in pass rate are monitored over time.*

Data: Student Outcomes-Course Matrix:

The Student Outcomes-Course Matrix has been updated to include data from courses on the Fall 2019 and Spring 2020 sampling schedule, in Table 1 below. Grey boxes indicate a course which is sampled in a different semester. Green, yellow, or red boxes contain the percentage of students who passed the outcome as measured in the course. Data collected during the 2019-2020 cycle show strong student achievement of almost all Outcomes. Only **Outcome 1** (identify, formulate, and solve complex engineering problems) has a measure in the "yellow" zone: a single instance from 150B with a 72% pass rate. This is nearly at the "yellow-green" borderline of 75%, and not past the action threshold, but is worth some discussion by faculty.

Table 1: Analysis of Outcome Assessment Templates for Student Outcomes				% Passing
ABET Student outcome	**Measure from Outcome Assessment Templates**	**Year Analyzed**	**Year of Study**	**Spring 2020**
1- an ability to identify, formulate, and solve complex engineering problems by applying the principles of engineering, science, and mathematics	**141 - Thermodynamics** - Course Outcome #6: Calculate equilibrium composition of conversion in a homogeneous or heterogeneous chemical reaction.	2019, 2021	Sophomore	
	142 - Reaction Engineering - Course Outcome #6: Use the energy balance for either an adiabatic chemical reactor, a wall-cooled reactior, or a non-isothermal catalyst pellet, in conjunction with theh mole balance, to find the reaction rate.	2020, 2022	Junior	94%
	150A - Transport - Course Outcome #3: Solve for the velocity field in simple geometries using the differential forms of conservation of mass and linear momentum.	2019, 2021	Sophomore	
	150B - Transport and Separations - Course Outcome #1: Solve steady-state and transient mass transport problems of engineering significance that involve diffusion and convection.	2020, 2022	Junior	72%
	162- Process Dynamics and Control - Course Outcome #2: Use principles of chemistry and physics to derive mechanistic process models**.**	2020, 2022	Senior	77%
2-an ability to apply engineering design to produce soltuions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors	**40 - Intro to Chem Eng Design** - Course Outcome #1: Create a process flow diagram for a chemical or physical process protocol, applying standard process flow diagram conventions including stream labeling and standard names for physical and chemical unit operations.	2019, 2021	Freshman	
	140 - Chem Process Analysis - Course Outcome #8: Determine the design compromise for determining the temperature in a BSTR, a CSTR or a PFR.	2019, 2021	Sophomore	
	150B - Transport and Separations - Course Outcome #4: Design a binary distillation unit with various design specifications.	2020, 2022	Junior	81%
	160 - Process Design - Course Outcome #3: Optimize the process simulation flowsheet based on heuristics, scheduling considerations, and the results of systematic variation of process parameters in the simulation package.	2020, 2022	Senior	100%
	160 - Process Design - Course Outcome #8: Use profitability measures (such as net present value or internal Rate of Return) to compare different process optimization schemes.	2020, 2022	Senior	100%
3- an ability to communicate effectively with a range of audiences	**40 - Intro to Chem Eng Design** - Course Outcome #7: Effectively communicate technical ideas to a mixed audience of technical novices and experts.	2019, 2021	Freshman	
	154 - Unit Operations Laboratory - Course Outcome #6: Effectively present technical information to an audience of technical experts.	2020, 2022	Senior	100%
	160 - Process Design - Course Outcome #12: Communicate key process design decisions and analysis to an audience of technical project managers.	2020, 2022	Senior	100%
Color Key:				
Grey - No data; course not offered or not on sampling schedule this semester				
Green - Over 75% of students passed this outcome by the course direct measure				
Yellow - Over 50% of students passed this outcome by the course direct measure				
Red - Action level: 50% or fewer of students passed this outcome by course direct measure				

Table 1 (cont): Analysis of Outcome Assessment Templates for Student Outcomes				% Passing
ABET Student outcome	**Measure from Outcome Assessment Templates**	**Year Analyzed**	**Year of Study**	**Spring 2020**
4- an ability to recognize ethical and professional responsibilities in engineering situation and make informed judgments, which hmust consider the impact of engineering soltuions in global, economic, environmental, and societal contexts	**140 - Chem Process Analysis -** Course Outcome #9: Deconstruct chemical accidents, runaway reactors, adiabatic flames.	2019, 2021	Sophomore	
	142 - Reaction Engineering - Course Outcome #7: Analysis and awareness of reactive hazards including but not limited to hot spots and thermal runaway in packed-bed and stirred-tank reactors.	2020, 2022	Junior	
	154 - Unit Operations Laboratory - Course Outcome #8: Recognize the ethical responsibility of engineers, and articulate morally justified solutions to ethical problems.	2020, 2022	Senior	95%
	160 -Process Design - Course Outcome #1: Discuss the principal issues in ethics, environmental protection and safety, including reactive hazards, as they relate to the design of new chemical and biological processes and retrofitting of older plants.	2020, 2022	Senior	100%
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	**40 - Intro to Chem Eng Design** - Course Outcome #6: Function effectively in teams to create a collaborative and inclusive environment for technical project work.	2019, 2021	Freshman	
	154 - Unit Operations Laboratory - Course Outcome #7: Function effectively on project teams, providing leadership to meet key objectives.	2020, 2022	Senior	100%
	160 - Process Design - Course Outcome #11: Function effectively on project teams by collaboratively establishing goals, planning tasks, and meeting objectives.	2020, 2022	Senior	100%
6- an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	**142 - Reaction Engineering** - Course Outcome #8: Use real or simulated experimental data to determine the reaction order for a compound involved in a chemical reaction.	2020, 2022	Junior	88%
	154 - Unit Operations Laboratory - Course Outcome #1: Set up and carry out an experimental plan for extracting information about chemical /physical processes.	2020, 2022	Senior	100%
7- an ability to aquire and apply new knowledge as needed, using appropriate learning strategies	**40 - Intro to Chem Eng Design** - Course Outcome #5: Acquire and apply new knowledge, using appropriate learning strategies.	2019, 2021	Freshman	
	160 - Process Design - Course Outcome #10: Acquire and apply new knowledge, using appropriate learning strategies.	2020, 2022	Senior	100%
Color Key:				
Grey - No data; course not offered or not on sampling schedule this semester				
Green - Over 75% of students passed this outcome by the course direct measure				
Yellow - Over 50% of students passed this outcome by the course direct measure				
Red - Action level: 50% or fewer of students passed this outcome by course direct measure				

Part 2: Indirect Measures: Student Survey and Focus Group

Process excerpt:

a. *Graduating seniors are surveyed about the Student Outcomes on the senior graduation survey administered by the College of Chemistry.*
    i. *Graduating seniors are asked to rate the level to which the curriculum prepared them to attain each Student Outcome.*
    ii. *The survey is administered in spring of each year.*
    iii. *Survey completion is required for tickets to the Commencement ceremony. (Note: there was no Commencement ceremony in 2020, so this incentive was absent).*
    iv. *Survey results are reported to the Chemical and Biomolecular Engineering Department in spreadsheet format by August of the same calendar year.*

b. *Student focus groups occur twice each academic year, giving student representatives a forum to discuss curricular issues with faculty representatives.*
    i. *The AIChE Lunch is each fall semester, with 5-10 students from the Berkeley AIChE Student Section, including officers and non-officers across all years of study.*
    ii. *The Honors Tea is each spring semester, with 10-15 chemical engineering honors students across all years of study. **
    iii. *During these focus groups, students are asked to consider the Student Outcomes and comment on those that the curriculum addresses well, and those that should be improved.*
    iv. *The student feedback is recorded in the meeting minutes.*

**In the Spring 2020 semester, the Honors Tea was held via Zoom.*

Data: Senior Survey:

Graduating seniors were surveyed on the degree to which they agree that they possess each skill or ability described in the Student Outcomes (1-7). There were 72 responses for this year's survey. Their responses are summarized in Table 2, below.

This is the second year of data collection for the new Student Outcomes. A comparison to the previous years data is shown in Table 3. All outcomes have strong degrees of agreement, ranging from 72% to 89% agreement, and very low degrees of disagreement, with only 0% to 3% of respondents marking disagreement.

Outcome 5 (function effectively on teams) was rated highest this year, with 89% of respondents agreeing they have this ability, and 0% disagreeing that they have this ability. This rating is similar to the level of agreement in the previous year, where it was also the outcome with the highest rating.

Outcome 2 (apply engineering design to produce solutions that meet specified needs) was rated lowest this year, with 72% of respondents agreeing that they have this ability, and 3% disagreeing. This rating is similar to the level of agreement during the previous year, where it was also rated lowest.

Table 2: Senior Survey Responses 2020. Students were asked if they have each ability.

College of Chemistry Exit Survey : Spring 2020 ABET Questions - Chemical Engineering Majors	Disagree		Neutral		Agree		Total
	%	number	%	number	%	number	
1- An ability to identify, formulate, and solve complex engineering problems by applying the principles of engineering, science, and mathematics	0%	0	17%	12	83%	60	72
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%	2	25%	18	72%	52	72
3- An ability to communicate effectively with a range of audiences	0%	0	19%	14	81%	58	72
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	0%	0	15%	11	85%	61	72
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	0%	0	11%	8	89%	64	72
6- An ability to develop and conduct appropriate experimentation analyze and interpret data, and use engineering judgment to draw conclusions	3%	2	15%	11	82%	59	72
7- An ability to acquire and apply new knowledge as needed, using appropriate learning strategies	0%	0	15%	11	85%	61	72

Table 3: Comparison of Senior Survey Responses from the preceding two years (since moving to Outcomes 1-7):

Senior Survey ABET Outcomes: Comparison of 2019 and 2020							
Percentage of Students Agreeing they have this ability							
	Outcome 1	Outcome 2	Outcome 3	Outcome 4	Outcome 5	Outcome 6	Outcome 7
Year							
2019	78%	71%	79%	81%	86%	79%	84%
2020	83%	72%	81%	85%	89%	82%	85%

Ratings for each Outcome, 1-7 are stable or have moderately increased this year compared to last year. There is consistency in the highest (Outcome 5) and lowest (Outcome 2) rated outcomes between the two years.

Data: Student Outcomes Reflections from the AIChE Student-Faculty Focus Group:

The fall 2018 AIChE Student-Faculty Focus Group was moved to spring 2019 (April 2, 2019) due to campus closures for wildfires in the fall. The results of the spring 2019 discussion are summarized in the Summary of ABET Student Outcomes Assessment, 2018-2019. Plans for the fall 2019 student-faculty lunch were moved to spring 2020, and ultimately cancelled due to the public health shelter-in-place orders related to the pandemic. However, an expanded, virtual Honor Student Tea (described below) included many of the students and faculty who would have attended the AIChE Student-Faculty focus group, and the group reviewed ABET Outcomes, the undergraduate curriculum, teaching with technology, and resources and support for students.

Data: Student Outcomes Reflections from the Honors Student Tea, Monday, April 13, 2020 (via Zoom):

This year's tea was virtual due to the pandemic, but included a full-group discussion on issues including the timing of core course offerings (planning to offer all core courses each semester), student support systems like tutoring and counseling services, thermodynamics coverage (and the Chem 120A/Physics 137A requirement), communications training, and Student Outcomes 1-7 specifically.

Responding to Prompt on ABET Student Outcomes:

Students in the group felt that technical aspects of problem solving (**Outcome 1**) are well covered in the curriculum. Students particularly highlighted that 40, 140, 150A, and 154 were helpful in developing their skills in solving engineering problems that integrated engineering, science, and mathematics. 154 was highlighted for introducing students to more practical aspects of engineering.

On **Outcome 2**, students noted that 140, through biogas versus battery recycling analysis, provided social and other repercussions of technology, and that safety was introduced in 140 in the context of the Bhopal chemical accident. Safety and ethics were also discussed in 154 in terms of the Deepwater Horizon explosion and oil spill, and in 160 in the context of process engineering. Some students indicated a desire for more international case studies.

154 and 160 were deemed excellent classes by students for honing communication skills (**Outcome 3)** in the form of oral and written reports; ChemE car and other clubs also provide exposure to students on making presentations, both verbally and orally (i.e. Biofuel Technology Club). A few students expressed an interest in a technical communications course, such as 185, to provide more comprehensive training and practice in oral and written communications.

Most students felt that they are well-educated in the area of ethical and societal impacts and professionalism (**Outcome 4**). They cited core courses 154 and 160 and elective courses to develop

these skills. Some expressed an interest in integrating ethics into all core courses, or having an ethics elective that would satisfy breadth requirements.

In response to **Outcome 5** on teamwork, students cited the many courses with a team project (40, 140, 154, 160), and the use of team-based problem solving in discussions. Students felt that 154 was particularly helpful in this regard; and noted that the Chemistry 4B special project was also an excellent teamwork exercise.

On **Outcome 6** (experimental design, data analysis & interpretation), students noted that 154 emphasizes everything related to this outcome. In addition, students found the Chem 4B project very helpful.

When considering **Outcome 7** (acquiring and applying new knowledge), students commented that it is developed in homework sets and students working in faculty research labs.

In general, students felt that:

- the curriculum is very strong on Outcome 1, 5, and 6
- the new peer tutoring center is a big help
- different strategies for expanding the ethics component should be considered
- more opportunities for projects and independent research should be made available.

Some students also questioned the necessity of the Chem 120A/ Phys 137A requirement; and some expressed a desire for an engineering mathematics course that would better prepare them in differential equations, numerical methods, and statistics.

Part 3: Summary of Response to 2018-2019 Cycle

At the faculty retreat in January 2020, the faculty discussed the data from the 2018-2019 continuous improvement cycle. During that cycle, there was one metric each in the matrix of two direct measures where the measure was in the "yellow" 50-75% pass range. The two outcomes were: **Outcome 2** (apply engineering design to produce solutions), and **Outcome 4** (recognize ethical and professional responsibilities; consider impacts); both of which have one measure each in the "yellow" zone. This is not below our "action threshold", and both measures were from the same course (140), which had a smaller group of students than in recent past semesters, and the enrollment consisted primarily of transfer students, who have a different background preparation compared to those that enter our program as freshmen.

During that same cycle, student survey and focus group responses suggested some focus on improvement in Outcomes 2(apply engineering design to produce solutions that meet specified needs), and more opportunities to practice and receive feedback on communication skills and to work on team projects or independent research. How to make 154 (the unit operations laboratory) more resilient to temporary shutdowns as had occurred during the fall semester due to wildfires was also discussed.

The faculty concluded that the metrics are fine for now. They noted that offering every course every semester segregates the transfer students to the “off” (lower enrollment) semester, and the mathematical preparation of these students should be monitored. We discussed opportunities to provide independent research opportunities and internships and revisited the discussion of a technical communications course. There was no consensus regarding the technical communications course, in part because offering all core courses each semester already places strong constraints on non-core course offerings.