Summary of ABET Student Outcomes Assessment, 2018-2019

Bachelor of Science in Chemical Engineering

Chemical and Biomolecular Engineering Department

University of California, Berkeley

July 2, 2019

Executive Summary

This report presents the direct and indirect student outcomes assessment data collected from instructors and students during the 2018-2019 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 and updated November 28, 2018 to reflect new Student Outcomes 1-7. 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 2018-2019 academic year. Part 2 reports the indirect measures results by first reviewing the process and then presenting data from the spring 2019 graduating senior survey, and the 2018-2019 student focus groups (AIChE Student-Faculty Focus Group and Honors Student Tea). Part 3 summarizes the responses and outcomes from the 2017-2018 cycle.

Direct measures from student classwork show good achievement of most outcomes during the 2018-2019 year, but **Outcome 2** (apply engineering design to produce solutions), and **Outcome 4** (recognize ethical and professional responsibilities; consider impacts) each had one course work measure in the 50-75% pass range that should be reviewed. Survey and focus group responses show that students continue to be confident about their skills and abilities in most Student Outcomes, especially **Outcome 5** (function effectively on teams), **Outcome 7** (acquire and apply new knowledge) and **Outcome 1** (solve complex engineering problems). They suggest some focus on improvement in **Outcome 2** (apply engineering design to produce solutions that meet specified needs), and more opportunities to practice and get feedback on communication skills (**Outcome 3**).

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 Spring 2019 sampling schedule, in Table 1 below. Spring 2019 is the first semester for which Student Outcomes 1-7 are adopted. No data were collected during the fall 2018 semester during transition to the new

Outcomes. Green, yellow, or red boxes contain the percentage of students who passed the outcome as measured in the course. Grey boxes indicate a course that is sampled in a different semester. Data collected during the 2018-2019 cycle show strong student achievement of most Outcomes, with some discussion warranted to examine the results for **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 past the action threshold, but worth considering. It may be relevant to note that these measures were both from the same course, 140, which had a smaller group of students than recent past semesters, and a different background preparation compared to recent past semesters, during our transition to offering all core courses each semester.

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 2019**
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 or conversion in a homogeneous or heterogeneous chemical reaction.	2019, 2021	Sophomore	82%
	142 - Reaction Engineering - Course Outcome #6: Use the energy balance for either an adiabatic chemical reactor, a wall-cooled reactor, or a non-isothermal catalyst pellet, in conjunction with the mole balance, to find the reaction rate.	2020, 2022	Junior	
	150 A - 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	97%
	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	
	162 - Process Dynamics and Control - Course Outcome #2: Use principles of chemistry and physics to derive mechanistic process models.	2020, 2022	Senior	
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	**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	91%
	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	55%
	150B - Transport and Separations - Course Outcome #4: Design a binary distillation unit with various design specifications.	2020, 2022	Junior	
	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	
	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	
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	96%
	154 - Unit Operations Laboratory - Course Outcome #6: Effectively present technical information to an audience of technical experts.	2020, 2022	Senior	
	160 - Process Design - Course Outcome #12: Communicate key process design decisions and analysis to an audience of technical project managers.	2020, 2022	Senior	

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 2019**
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	**140 - Chem Process Analysis** - Course Outcome #9: Deconstruct chemical accidents, runaway reactors, adiabatic flames.	2019, 2021	Sophomore	65%
	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	
	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 older plants.	2020, 2022	Senior	
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** - Couse Outcome #6: Function effectively in teams to create a collaborative and inclusive environment for technical project work.	2019 ,2021	Freshman	100%
	154 - Unit Operations Laboratory - Course Outcome # 7: Function effectively on project teams, providing leadership to meet key objectives.	2020, 2022	Senior	
	160 - Process Design - Outcome #11: Function effectively on project teams by collaboratively stablishing goals, planning tasks, and meet objectives.	2020, 2022	Senior	
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	
	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	
7- an ability to acquire and apply new knowledge as needed, using appropriate learning strategies	**40 - Intro to Chemical Engineering Design** - Course Outcome #5: Acquire and apply new knowledge, using appropriate learning strategies.	2019, 2021	Freshman	100%
	160 - Process Design - Course Outcome #10: Acquire and apply new knowledge, using appropriate learning strategies.	2020, 2022	Senior	

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.*
    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.*

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 91 responses for this year's survey. Their responses are summarized in Table 2, below.

Table 2: Senior Survey Responses 2019. Students were asked if they have each ability.

College of Chemistry Exit Survey: Spring 2019 ABET Questions - Chemical Engineering Majors							
	Disagree		Neutral		Agree		Total
1-An ability to identify, formulate, and solve complex engineering problems by applying the principals of engineering, science, and mathematics	2%	2	20%	18	78%	71	91
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	4%	4	24%	22	71%	65	91
3-An ability to communicate effectively with a range of audiences	0%	0	21%	19	79%	72	91
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	2%	2	16%	15	81%	74	91
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	14%	13	86%	78	91
6-An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	1%	1	20%	18	79%	72	91
7-An ability to acquire and apply new knowledge as needed, using appropriate learning strategies	1%	1	15%	14	84%	76	91

This is the first year of data collection for the new Student Outcomes, so these data will serve as a baseline moving forward. All outcomes have strong degrees of agreement, ranging from 71% to 86% agreement, and very low degrees of disagreement, with only 0% to 4% of respondents marking disagreement.

Outcome 5 (function effectively on teams) was rated highest this year, with 86% of respondents agreeing they have this ability, and 0% disagreeing that they have this ability. This rating is similar to the level of agreement on a similar teamwork outcome during the previous ABET cycle (Outcome d-84% agreed).

Outcome 2 (apply engineering design to produce solutions that meet specified needs) was rated lowest this year, with 71% of respondents agreeing that they have this ability, and 4% disagreeing. This rating is similar to the level of agreement on a similar design outcome during the previous ABET cycle (Outcome c-66% agreed).

Data: Student Outcomes Reflections from the AIChE Student-Faculty Focus Group, April 2, 2019:

This year, the annual lunch focus group with AIChE students was offered in the spring, due to school closures for wildfires in November. Twelve AIChE officers and members spanning first year through senior year attended. Four members of the faculty were present, especially including members of the Undergraduate Education Committee. In addition to comments on the ABET Outcomes, below, the group also discussed the curriculum, teaching with technology, and resources and support for students.

Reviewing the Student Outcomes 1-7:

Students report that **Outcome 1** (identify, formulate, solve complex engineering problems) is very strong in the curriculum.

Students indicated that **Outcome 2** (apply engineering design to produce solutions) is done well in the curriculum to address public safety and welfare. They cite Chem Eng 40 as a place that builds this emphasis in a sustainability-focused project, and report that problem sets and design projects throughout the rest of the curriculum emphasize the centrality of sustainability. They note that the curriculum could do more to address global issues. They suggest offering more choice in design projects, or letting students propose their own design topics.

In response to **Outcome 3** (communicate effectively with wide range of audiences) the students would like to see more communications emphasis, earlier and more often beyond what is done in 40, 154, and 160. They suggest bringing back 185, the technical communications course, or integrating technical communications into additional units of 40. They suggest giving opportunities to present in discussion sections. They suggest giving upperclassmen a chance to present to underclassmen. One student noted that their strong communication skills made a good impression on employers. The undergraduate research fair and Chem 4B projects are good opportunities to practice these skills. Students commented that working in faculty research groups helps develop communication skills.

Students commented that the curriculum is doing a good job of developing ethical and professional responsibilities (**Outcome 4**). One student noted that every course highlights the importance of safety, ethics, and reactive hazards. MSE 45 also has a deep dive ethics topic assignment. Students develop skills in the AIChE online process safety certificate required for 154. Some electives also have a focus in this area.

Outcome 5 asks about functioning effectively on a team. Students pointed out that they have many group project throughout the curriculum (40, 140, 154, and 160), but none in 141, 150A, 142, and 150B, which are clustered together in time. They suggest integrating team projects into one of these or adjusting the 142 individual project to make it team-oriented.

Students had no comments about **Outcome 6** (develop and conduct experiments), or **Outcome 7** (acquire and apply new knowledge) except that they indicated that all seven outcomes, including these, are developed in faculty-mentored research.

Data: Student Outcomes Reflections from the Honors Student Tea, April 23, 2019:

This year's tea included a full-group discussion on issues including peer tutoring, class scheduling, grades, research, diversity and inclusion, the new student experience, and Student Outcomes 1-7 specifically.

Responding to Prompts on ABET Student Outcomes:

All students in the group feel comfortable with the technical aspects of problem solving (**Outcome 1**), and note that 140, 150A, 142, 150B, and 141 were key to building problem-solving proficiency.

On the topic of design (**Outcome 2)**, students really like design elements and non-ideality in 40, 140, 160, 154, 162, 142. Some students felt that 160 did not seem useful because the focus was narrow in the process engineering area. They prefer to have project options that cross industries or areas of focus.

Students wish to have the 185 technical communications course back, to more fully support **Outcome 3**. They note that the training in 154 is not sufficient because they need more training and practice to build skills.

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

In response to **Outcome 5** on teamwork, students cite the many courses with a team project, and the use of team-based problem solving in discussions. They noted the way various perspectives were welcomed in a discussion-based Negative Emissions Technology journal club, and said that study groups and peer tutoring are helpful.

Students described the Chem 4B special project as very helpful with developing **Outcome 6** because they experimental plan sometimes requires trouble-shooting.

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

<u>Part 3: Summary of Response to 2017-2018 Cycle</u>

At the faculty retreat in January 2019, the faculty discussed the data from the 2017-2018 continuous improvement cycle. During that cycle, there was one metric each in the matrix of direct measures where the measure was in the "yellow" 50-75% pass range. This is not below our "action threshold". The outcomes for those were: **Outcome e** (problem solving), **Outcome h** (broad education to understand impacts), and **Outcome k** (techniques, skills, and tools). During that same cycle, student survey and focus group responses suggest some focus on improvement in **Outcomes c** (design with constraints)**, h** (broad education to understand impacts)**, j** (contemporary issues)**, and k** (techniques, skills, and tools). Students recommend discussion on continued integration of communications (**Outcome g**), and the role of project-based learning.

Reviewing the data, the faculty discussed in particular performance on the metric within **Outcome k** which measured "Analytically and computationally solve ordinary differential equations" in the context of Chem Eng 162, Process Dynamics and Control, which 59% of students passed in the spring 2018

semester. The instructor clarified that student performance on numerical solutions is alright, but that analytical solution skills are less strong. We noted that this drop in the student performance compared to previous terms could be connected to decreased coverage of differential equations in the MATH 54 course. The faculty agreed to: **Affirm ODE solutions in the classroom and continue to monitor performance via the 162 Outcome Assessment Template.** Student performance in this same metric during the spring 2019 term was **93% passing**.

The faculty concluded that the other metrics were OK for now. We discussed opportunities to engage peer evaluation and feedback, especially qualitative or quantitative feedback with reduced weight, for projects and communications deliverables. Faculty teaching the 154 course have been in communication with faculty teaching the 160 course, and are considering the use of coordinated grading rubrics and materials for written and oral reports.