Summary of ABET Student Outcomes Assessment, 2021-2022

Bachelor of Science in Chemical Engineering

Chemical and Biomolecular Engineering Department

University of California, Berkeley

July 1, 2022

Executive Summary

This report presents the direct and indirect student outcomes assessment data collected from instructors and students during the 2021-2022 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 2021-2022 academic year. Part 2 reports the indirect measures results by first reviewing the process and then presenting data from the spring 2022 graduating senior survey, and the 2021-2022 student focus groups (AIChE Student-Faculty Focus Group and Honors Student Tea). Part 3 summarizes the responses and outcomes from the 2020-2021 cycle.

Direct measures from student classwork show very good achievement of all outcomes during the 2021-2022 year, with all Outcomes showing over 75% of students passed each outcome by the course direct measure. 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), **Outcomes 3** (ability to communicate effectively), **Outcome 5** (teamwork), Outcome 6 (design, conduct, analyze and interpret experiments), and **Outcome 7** (acquire and apply new knowledge). They suggest some focus on improvement in **Outcome 2** (apply engineering design to produce solutions that meet specified needs). Some students expressed that the present emphasis of ethics is too late in curriculum. and that more content on ethics outside of safety related consideration is needed.

As a note of context, Prof. Susan Muller, who was in charge of our ABET process since 2020, retired in summer of 2021 and Dr. Beheshti Pour assumed responsibility for ABET as of that day. As a result, the 2021-2022 summary report was prepared during this transition.

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 2021 and Spring 2022 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 2021-2022 cycle show strong student achievement of all Outcomes. All Outcomes have measures in the “green” zone, indicating that over 75% of students passed the Outcome by the course direct measure.

Table 1: Analysis of Outcome Assessment Templates for Student Outcomes				% Passing	
ABET Student Outcome	**Measure from Outcome Assessment Templates**	**Year Analyzed**	**Year of Study**	**Fall 2021**	**Spring 2022**
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, 2023	Sophomore	80%	
	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, 2024	Junior		77%
	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, 2023	Sophomore	89%	
	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, 2024	Junior		78%
	162 - Process Dynamics and Control - Course Outcome #2: Use principles of chemistry and physics to derive mechanistic process models.	2020, 2022, 2024	Senior		84%
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, 2023	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, 2023	Sophomore	90%	
	150B - Transport and Separations - Course Outcome #4: Design a binary distillation unit with various design specifications.	2020, 2022, 2024	Junior		94%
	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, 2024	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, 2024	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, 2023	Freshman		
	154 - Unit Operations Laboratory - Course Outcome #6: Effectively present technical information to an audience of technical experts.	2020, 2022, 2024	Senior		100%
	160 - Process Design - Course Outcome #12: Communicate key process design decisions and analysis to an audience of technical project managers.	2020, 2022, 2024	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

ABET Student Outcome	Measure from Outcome Assessment Templates	Year Analyzed	Year of Study	Fall 2021	Spring 2022
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, 2023	Sophomore	95%	
	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, 2024	Junior		90%
	154 - Unit Operations Laboratory - Course Outcome #8: Recognize the ethical responsibility of engineers, and articulate morally justified solutions to ethical problems.	2020, 2022, 2024	Senior		93%
	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, 2024	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** - Couse Outcome #6: Function effectively in teams to create a collaborative and inclusive environment for technical project work.	2019 ,2021, 2023	Freshman		
	154 - Unit Operations Laboratory - Course Outcome # 7: Function effectively on project teams, providing leadership to meet key objectives.	2020, 2022, 2024	Senior		84%
	160 - Process Design - Outcome #11: Function effectively on project teams by collaboratively stablishing goals, planning tasks, and meet objectives.	2020, 2022, 2024	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, 2024	Junior		89%
	154 - Unit Operations Laboratory - Course Outcome #1: Set up and carry out an experimental plan for extracting information about chemical/physical processes.	2020, 2022, 2024	Senior		100%
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, 2023	Freshman		
	160 - Process Design - Course Outcome #10: Acquire and apply new knowledge, using appropriate learning strategies.	2020, 2022, 2024	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.*
    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. *This year, due to the change of our ABET coordinator, it was held in the Spring semester.*
    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 88 responses for this year's survey; this is a significantly lower response rate than in previous years, possibly because of the online nature of the academic year and the absence of the incentive of Commencement tickets. Their responses are summarized in Table 2, below.

This is the fourth year of data collection for the new Student Outcomes. A comparison to the three previous years data is shown in Table 3 and Figure 1 below. All outcomes have strong degrees of agreement, ranging from 72% to 91% agreement, and very low degrees of disagreement, with only 0% to 2% of respondents marking disagreement.

Outcomes 5 (function effectively on teams) and **Outcome 7** (acquire and apply new knowledge) were rated highest this year, with 91% and 83% of respondents, respectively, agreeing they have this ability, and 1%, disagreeing that they have this ability.

Outcome 2 (apply engineering design to produce a solution that meets specified needs) was rated lowest this year, with 72% of respondents agreeing that they have this ability, and 2% disagreeing. This rating is modestly lower than the three preceding years. **Outcome 6** and **Outcome 7** which are tied closely to CBE154, the unit operation laboratory**,** were rated higher compared to last year that the instruction was remote due to pandemic.

Table 2: Senior Survey Responses 2022. Students were asked if they have each ability.

College of Chemistry Exit Survey: Spring 2022							
ABET Questions - Chemical Enineering 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	19%	17	78%	69	88
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	2%	2	25%	22	72%	63	87
3-An ability to communicate effectively with a range of audiences	1%	1	22%	19	77%	66	86
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	1%	1	20%	17	79%	69	87
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	1%	1	8%	7	91%	78	86
6-An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	1%	2	20%	17	78%	67	86
7-An ability to acquire and apply new knowledge as needed, using appropriate learning strategies	1%	2	15%	13	83%	71	86

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

Senior Survey ABET Outcomes: Comparison of 2019, 2020, 2021, and 2022							
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%	79%	81%	86%	86%	79%	84%
2020	83%	81%	85%	85%	89%	82%	85%
2021	81%	85%	87%	87%	87%	77%	79%
2022	78%	72%	77%	79%	91%	78%	83%

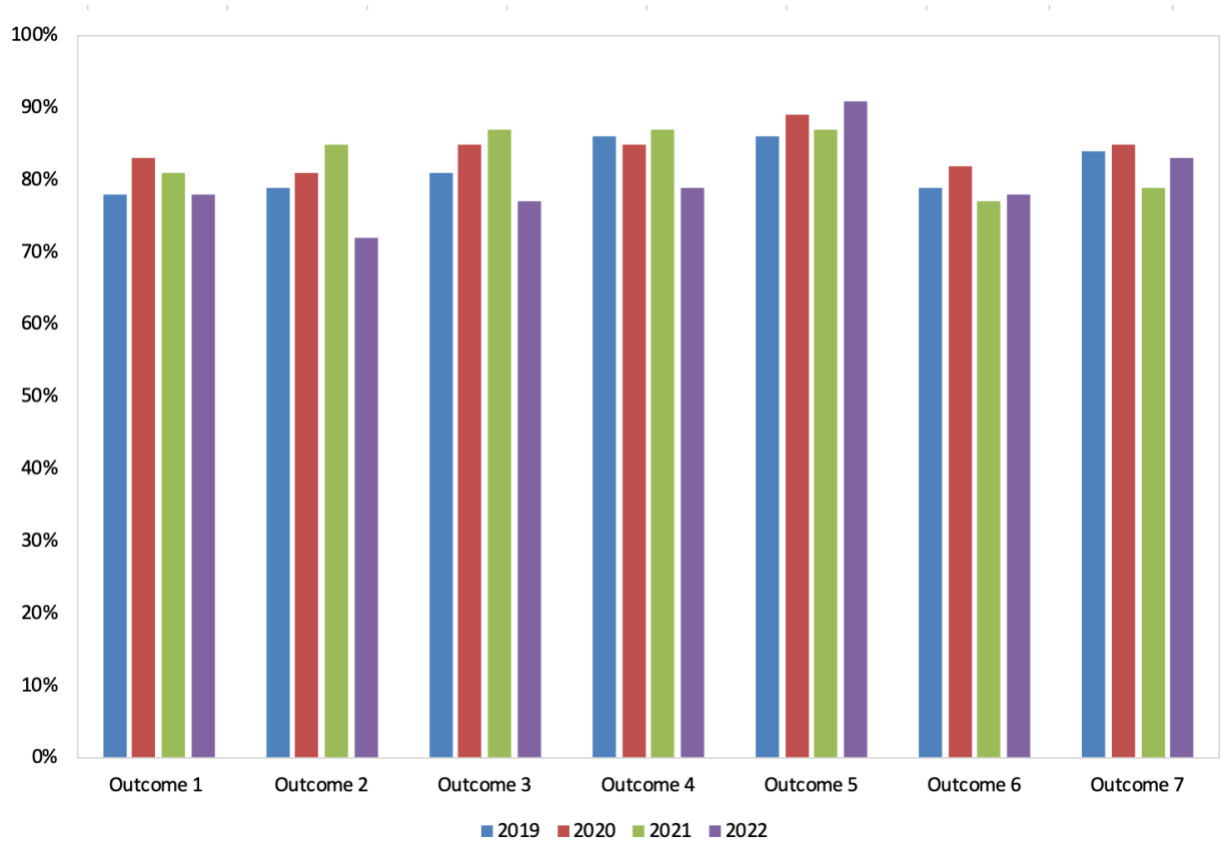

Figure 1. Comparison of Senior Survey Responses from the four years of data collection (2019-2022).

As can be seen in Figure 1, ratings for each Outcome 1-7 are fairly stable across the four years.

Outcome 2 (apply engineering design to produce a solution that meets specified needs) was rated lowest this year, with 72% of respondents agreeing that they have this ability, 25% Neither agree nor disagree (Neutral), and 2% disagreeing.
Outcome 5 (function effectively on teams) was rated highest this year, with 91% of respondents agreeing they have this ability, and 1% disagreeing that they have this ability.

Data: Student Outcomes Reflections from the AIChE Student-Faculty Focus Group, April 25, 2022:

The fall 2021 AIChE Student-Faculty Focus Group was moved to spring 2022 due to the transition of ABET coordinator. The event was held in person on April 25, 2022. Eight AIChE officers and members spanning freshman through senior year attended. Four members of the faculty attended, including department chair Jeffrey Reimer, two members of the Undergraduate Education Committee. In addition to comments on the ABET Outcomes (summarized below), the group also discussed the curriculum, and resources for students. A more detailed summary is available in the department's google drive folder.

Reviewing the Student Outcomes 1-7:

Outcome 1 (identify, formulate, and solve complex engineering problems): Students reported that this is very well covered in a range of courses. They highlighted that Berkeley focuses heavily on concepts, theory; not industrial applications. While some other schools require internships and have internship prep courses.

Outcome 2 (apply engineering design to produce solutions): Students felt that the curriculum met this outcome but some saw room for improvement, noting that economics and environmental factors were covered very well but other aspects were covered little. Moreover, students noted that CBE90 covers some social and global factors but not public health

Outcome 3 (communicate effectively with a wide range of audiences): Students considered themselves well-prepared for technical communication but would like more practice on how to communicate with a lay audience. They particularly highlighted: 154 helps with efficient communication. AIChE officers also highlighted that many AIChE sponsored activities (outreach, etc.) offer students a chance to talk to non-technical audiences. Some students felt that more instruction on this topic is needed in the core curriculum.

Outcome 4 (ethical and professional responsibilities): students felt that present emphasis on this topic is too late in curriculum and they would like to have a specific course on ethics. They noted that: BioE has an ethics course. Data science has an ethics minor; why not CBE? Students mentioned that AIChE online training on Safety and Ethics are ok but should be done before junior year. They noted that some electives cover these topics but where they mix with STEM is missing.

Outcome 5 (function effectively on a team): Students expressed confidence in their ability to function effectively on a team. They noted that courses that have design projects such as 142 and 150B encourage teamwork and collaborations. Also, they belive that 154 peer evaluations and presentations make a good balance for accountability.

Outcome 6 (design, conduct, analyze, and interpret experiments): Students noted that 154 is the course that best addresses this outcome. It is the main CBE course where you do experiments and data analysis.

Outcome 7 (acquire and apply new knowledge): students requested more guidance on how to acquire and apply new knowledge...what resources to use...where to look. They appreciate industrial experience comments in 170B on columns and in 170A basic sample calculations.

Data: Student Outcomes Reflections from the Honors Student Tea, Monday, April 26, 2022:

This year's tea included a full-group discussion on issues including class scheduling, grades, research, diversity and inclusion, the Chem 120A/Physics 137A requirement, the new student experience, and Student Outcomes 1-7 specifically. Outcomes were discussed in smaller groups, and the full group synthesized the results and discussed other issues. Eight students and four faculty attended. The full list

of student attendees and the notes can be found in the CBE department's ABET folder on the Google drive.

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 142, 150B, 154, 160 and 176 were helpful in contextualizing concepts into practice.

Students felt that **Outcome 2** was well covered, noting that CBE40 final project was really helpful for project-based safety issues. They mentioned that CBE160, 170A, 170B and 154 do a good job on Ethics. Students also

On **Outcome 2**, students noted that ethics is adequately covered in 154 and 160, but felt there was not enough discussion about social and cultural factors. Students noted that CBE 40 final project was really helpful for project-based safety issues, and that 160 does a good job on Ethics. They also mentioned that 170A, 170B and 154 projects helped with this outcome.

Regarding **Outcome 3**, students considered themselves well-prepared noting that 154 is a crash course in communication. They also mentioned CBE40 final project as a great experience. They found Chem4B special project poster presentation very helpful and they mentioned that CBE160 and 170 L cover effective communication lectures. Students also found the extracurricular activities like clubs and research very helpful for improving their ability to communicate effectively with a range of audiences.

Most students felt that they are well-educated in the area of ethical and societal impacts and professionalism (**Outcome 4**). They mentioned that that in CBE154 students had to get the safety and ethics certificates from AIChE SAChE courses. Students think that these online courses should have been taken earlier.

In response to **Outcome 5** on teamwork, students felt well-prepared by 154 and 160 to function effectively in teams, and noted that 40 promotes these skills as well. 12A labs involved a lot of discussion.

With respect to **Outcome 6** (experimental design, data analysis & interpretation), some students indicated that analyzing and interpreting data is woven throughout the curriculum, and that 154 emphasizes everything related to this outcome.

When considering **Outcome 7** (acquiring and applying new knowledge), students commented that all CBE courses force you to apply and acquire new knowledge.

Some students also questioned the necessity of the Chem 120A/ Phys 137A requirement; and some expressed their regret that CBE40 is no longer offered. Students also brought up the system-wide issue of scheduling especially in senior year that there are a lot of conflicts among electives.

Part 3: Summary of Response to 2020-2021 Cycle

At the faculty retreat in January 2022, and at several faculty meetings in the Fall 2021 semester, the faculty discussed the data from the 2020-2021 continuous improvement cycle. During that cycle, only **Outcome 2** (apply engineering design to produce solutions) had a measure in the "yellow" zone: a single instance from 150B with a 47% pass rate. Survey and focus group data suggested students were confident with respect to all outcomes; they found electives very relevant and useful. Students think the curriculum is very broad and prepares them for many opportunities. They felt that the CBE faculty have been very supportive during this cycle, making accommodations for online learning. Some students expressed a desire for an engineering mathematics course that would better prepare them in differential equations, numerical methods, and statistics.

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.

During the retreat, faculty also addressed enrollment issues in 154 and 160, mathematics and statistics in the curriculum, replacing CBE 40 with a seminar (CBE 98) to introduce students to the discipline and practice of chemical engineering, and whether teaching every required course every semester is sustainable given our faculty size. The faculty voted to add a mathematics in chemical engineering course (CBE 130) to the curriculum, and agreed on a tentative syllabus. The faculty also expressed some enthusiasm for allowing CBE 170L as an alternative to 154 for some students, although a fuller consideration of this was referred to the Undergraduate Education Committee.