Summary of ABET Student Outcomes Assessment, 2022-2023
Bachelor of Science in Chemical Engineering
Chemical and Biomolecular Engineering Department
University of California, Berkeley
July 1, 2023

Executive Summary

This report presents the direct and indirect student outcomes assessment data collected from instructors and students during the 2022-2023 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 2022-2023 academic year. Part 2 reports the indirect measures results by first reviewing the process and then presenting data from the spring 2023 graduating senior survey, and the 2022-2023 student focus groups (AIChE Student-Faculty Focus Group and Honors Student Tea). Part 3 summarizes the responses and outcomes from the 2021-2022 cycle.
Direct measures from student classwork show good achievement of most outcomes during the 2022-2023 year, but **Outcome 1** (solve complex engineering problems), and **Outcome 2** (apply engineering design to produce a solution that meets specified needs) 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 4** (apply engineering design to produce solutions). Students suggest adding more safety talks to lower division courses. They appreciate the many available resources that College of Chemistry provides. However, they believe many students are not aware of these resources or don't use them. Some students also expressed that there are a lot of pre-requisites for elective classes which prevents them from taking electives and exploring different topics early in the curriculum.

As a note of context, core courses were no longer offered every semester, beginning Fall 2022 due to the lack of faculty. Moreover, UC Berkeley Graduate Student Instructors (GSIs) went on strike in November 2022 which disrupted grading and classes right before final exams and negatively impacted students' learning experiences. Thus, student course work was measured 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. *Beginning Fall 2022, core courses were no longer offered every single semester which might have impacted the order of assessment.*
    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 2022 and Spring 2023 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 2022-2023 cycle show strong student achievement of most Outcomes, with some discussion warranted to examine the results for **Outcome 1** (identify, formulate, solve complex engineering problems), and **Outcome 4** (apply engineering design to produce solutions), 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 Fall 2022 which was negatively impacted by the GSIs strike and resulted in instructors having to end up not grading homework and doing Finals in multiple choice or other easy-grading formats. 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 2022**	**Spring 2023**
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		89%
	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	50%%	
	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		76%
	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	75%%	
	162 - Process Dynamics and Control - Course Outcome #2: Use principles of chemistry and physics to derive mechanistic process models.	2020, 2022, 2024	Senior	92%	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	**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		
	150B - Transport and Separations - Course Outcome #4: Design a binary distillation unit with various design specifications.	2020, 2022, 2024	Junior	63%	
	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%	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%	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	88%	84%%
	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%	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 2022**	**Spring 2023**
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		
	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	100%	
	154 - Unit Operations Laboratory - Course Outcome #8: Recognize the ethical responsibility of engineers, and articulate morally justified solutions to ethical problems.	2020, 2022	Senior	93%	90%
	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	100%	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	Freshman		
	154 - Unit Operations Laboratory - Course Outcome # 7: Function effectively on project teams, providing leadership to meet key objectives.	2020, 2022	Senior	99%	84%
	160 - Process Design - Outcome #11: Function effectively on project teams by collaboratively stablishing goals, planning tasks, and meet objectives.	2020, 2022	Senior	100%	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	100%	
	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	77%	94%
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		
	160 - Process Design - Course Outcome #10: Acquire and apply new knowledge, using appropriate learning strategies.	2020, 2022	Senior	100%	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 110 responses for this year's survey and the responses are summarized in Table 2, below.

This is the fifth year of data collection for the new Student Outcomes. A comparison to the four previous years data is shown in Table 3 and Figure 1 below. All outcomes have strong degrees of agreement, ranging from 74% to 87% agreement, and very low degrees of disagreement, with only 0% to 3% of respondents marking disagreement.

Outcome 5 (function effectively on teams), **Outcome 7** (acquire and apply new knowledge), and **Outcome 4** (apply engineering design to produce solutions) were rated highest this year, with 87%, 86% and 86% of respondents, respectively, agreeing they have this ability, and 1% to 2%, 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 74% of respondents agreeing that they have this ability, and 2% disagreeing. This rating is higher than last year. **Outcome 6** and **Outcome 7** were also rated higher compared to last year.

Table 2: Senior Survey Responses 2023. Students were asked if they have each ability.

College of Chemistry Exit Survey: Spring 2023							
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	0%	0	16%	18	84%	93	111
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	24%	27	74%	82	111
3-An ability to communicate effectively with a range of audiences	3%	3	18%	20	79%	87	110
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	13%	14	86%	95	111
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%	2	11%	12	87%	97	111
6-An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	1%	1	19%	21	80%	89	111
7-An ability to acquire and apply new knowledge as needed, using appropriate learning strategies	1%	1	13%	14	86%	95	110
						Answered	110
						Skipped	1

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

Senior Survey ABET Outcomes: Comparison of 2019, 2020, 2021, 2022, and 2023							
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%
2023	84%	74%	79%	86%	87%	80%	86%

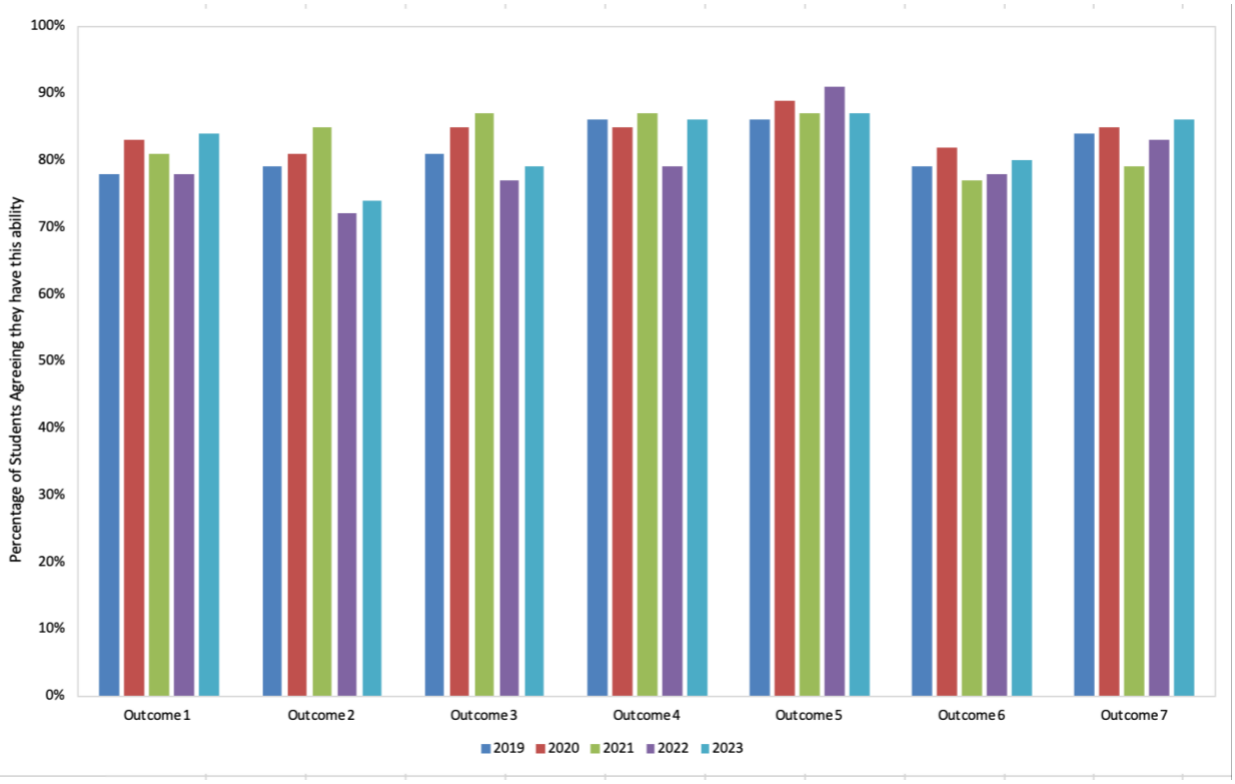

Figure 1. Comparison of Senior Survey Responses from the five years of data collection (2019-2023).

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

Outcome 2 (apply engineering design to produce a solution that meets specified needs) was rated lowest this year, with 74% of respondents agreeing that they have this ability, 24% Neither agree nor disagree (Neutral), and 2% disagreeing.
Outcome 5 (function effectively on teams) was rated highest this year, with 87% of respondents agreeing they have this ability, 11% Neither agree nor disagree (Neutral), and 1% disagreeing that they have this ability.

Data: Student Outcomes Reflections from the AIChE Student-Faculty Focus Group, April 24, 2023:
The AIChE Student-Faculty Focus Group was held in-person on April 24, 2023. Four AIChE officers and members spanning freshman through senior year attended. Four members of the faculty attended, including department chair Bryan McColskey, and three 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 box folder.
Reviewing the Student Outcomes 1-7:

Outcome 1 (identify, formulate, and solve complex engineering problems): Students felt that **Outcome 1** is well covered in a range of courses and that they are well equipped to solve complex engineering problems. They inquired about CBE130, Mathematics & Statistics in Chemical Engineering which will be a required co-requisite for CBE 140 for all new students beginning Fall 2022. Students also expressed their concern about the workload of the Fall of sophomore year considering taking three technical CBE130, CBE 140, and Chem 12A (two lab component courses).
They also inquired about E7 (Intro to Computer Programming for Scientists and Engineers) which teaches students computer programming in MATLAB language. Since CBE130 teaches Python, there is a debate on whether we should drop E7 or not. The UEC will be having a meeting with E7 instructor to discuss the advantages and disadvantages of MATLAB vs. Python programming language.
Outcome 2 (apply engineering design to produce solutions): Students indicated that Outcome#2 is mainly covered through 160 and 162. They suggested adding more safety talks to lower division courses. They noted that safety was covered briefly (50 min lecture) in 160. Two (50 min) lectures on Ethics and Safety in CBE154. Taking all the SAChE courses in 154 is not effective. The better option is to divide these safety and ethics online trainings throughout the curriculum as recommended at the AIChE website: Level One (Basic) Curriculum in sophomore year. Level Two (Intermediate) Curriculum in senior year.
Outcome 3 (communicate effectively with a wide range of audiences): Students considered themselves well-prepared for technical communication. They specially found 154 ORPTs and meetings with Prof. Tyson in CBE160, very helpful as they were similar to industry meetings and prepared them for that.
Outcome 4 (ethical and professional responsibilities): Students noted that 160 and some of 154 analysis questions best address this outcome.
Outcome 5 (function effectively on a team): Students expressed confidence in their ability to function effectively on a team. Students noted that these are really done in courses that have team projects such as 160 and 154.
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 noted that although studying at CoC is very tough, the curriculum does prepare students very well and, in the end, it's worth it. They mentioned that sometimes difficult problem sets could be discouraging. They appreciated the many available resources. However, they believe many students are not aware of these resources or don't use them.
Data: Student Outcomes Reflections from the Honors Student Tea, Monday, April 27, 2023:
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. 33 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 box.
Responding to Prompt on ABET Student Outcomes:

ABET Student Outcomes (1, 6, 7): Preparation for doing technical work in CBE (theoretical & practical foundation)

Students in the group felt that the ability to acquire and apply new knowledge (**Outcome 7**) is their strong suit and they agreed that the current ChemE classes taught them good problem-solving skills (**Outcome 1**). They were generally satisfied with mathematics & scientific background of curriculum.

Students mentioned that the bulk of ChemE concepts are learned starting sophomore spring, leaving students very little space to switch. Students think that CBE 40 was a good solution to that problem as it gave exposure to the kind of problems ChemEs solve.

Regarding **Outcome 6** (design, conduct, analyze, and interpret experiments), students believe that undergraduate research was very dominant because unit ops (& 170L) were lagging behind in skills developed versus research. They think that CBE 154 could perhaps be broken into smaller lab segments scattered throughout the curriculum. This is, however, logistically not feasible.

Students felt that the Alivisatos Undergraduate Research Program (AGURP) which ended a couple years ago used to provide students good exposure to computational methods and research. The quantum mechanics requirement was suggested to be an elective instead of a requirement and could perhaps be replaced or moved to later parts of the curriculum, where it becomes more important.

Students also think that there could be a Data Science concentration as the Data Science minor is becoming popular.

ABET Student Outcomes (2, 4): Ethics and Safety

With respect to **Outcome 2**, **4** (Ethics and Safety) students noted that the SAChE courses in CBE 154 are currently the most direct ways in which students learn safety and ethics. Students suggested whether they could have reserved seats in the popular Engineering Ethics class. Students indicated that Ethics is only emphasized in CBE 40, 154, and 160. Students suggested adding case studies and news articles to assignments about safety incidents to give real-world understanding. Overall, students think that the university is very conscious of these issues and so one get an understanding even without the curriculum itself.

ABET Student Outcomes (3, 5): Communication and Teamwork

In response to communication and teamwork, students felt that communication and teamwork was well covered through the capstone courses. Students particularly highlighted that CBE 154 and 160 are where most of the group work happens. Some noted that there are not many courses with group projects (CBE 40 had, but just removed); Chem 4B's special group project is pretty nice, but might be helpful for that project to be even longer. Students also noted that writing reports need better structures for feedback (especially from a narrative and accessibility perspective).

Part 3: Summary of Response to 2021-2022 Cycle

At the faculty retreat in January 2023, the faculty discussed the data from the 2021-2022 continuous improvement cycle. During that cycle, direct measures from student classwork show very good achievement of all outcomes, 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.

The faculty concluded that the metrics are fine for now. During the retreat, UEC summarized the undergraduate townhall discussions such as the overwhelming demand from students' end to have CBE40 back as they think it was a low stake, more fun and general introduction to chemical engineering - Students found CBE140 a bit too intense as a first class; students positive feedback in terms of the departmental support and their acknowledgment of the diversity of the faculty of CBE.

The faculty also discussed transitioning to Python from MATLAB given that MATLAB is an expensive, non open-source software and Python is becoming the universal go to programming language, although a fuller consideration of this was reffered to the Undergraduate Education Committee.

Moreover, the faculty discussed the new math course (CBE130) which is envisioned as a preparatory course that introduces the math that students will ultimately encounter in future courses. This course is replaced with CBE40 and the faculty's understanding is that this course should not be too advanced in nature, but rather introduce the mathematical concepts to be an aid to the core courses 141, 150A, 150B, 142 (e.g. solving 1st and 2nd order ODEs, numerical methods etc). Given that we are introducing the math course CBE 130, the faculty also discussed the value of Engineering 7 course which introduces computing to engineers particularly in the context of using MATLAB. The contingency plans in case the strike does not end were also discussed.