Summary of ABET Student Outcomes Assessment, 2020-2021

Bachelor of Science in Chemical Engineering

Chemical and Biomolecular Engineering Department

University of California, Berkeley

July 1, 2021

Executive Summary

This report presents the direct and indirect student outcomes assessment data collected from instructors and students during the 2020-2021 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 2020-2021 academic year. Part 2 reports the indirect measures results by first reviewing the process and then presenting data from the spring 2021 graduating senior survey, and the 2020-2021 student focus groups (AIChE Student-Faculty Focus Group and Honors Student Tea). Part 3 summarizes the responses and outcomes from the 2019-2020 cycle.

Direct measures from student classwork show very good achievement of all outcomes during the 2020-2021 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 4** (recognize ethical and professional responsibilities) and **Outcome 5** (teamwork). They suggest some focus on improvement in **Outcome 2** (apply engineering design to produce solutions that meet specified needs) and **Outcome 6** (design, conduct, analyze and interpret experiments); the latter arose because of the remote only instruction this academic year which moved 154 to online only. Some students recommend discussion on continued integration of communications (**Outcome 3**) and ethics (**Outcome 4)** across the curriculum; several students expressed an interest in more undergraduate research and internship opportunities.

As a note of context, due to public safety orders related to COVID-19, **all** instruction for this academic year was online. 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. *When outcomes are available for 2 semesters in the same academic year, both reported along with the average.*
    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 2020 and Spring 2021 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 2020-2021 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**	**Spring 2021**
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	97%
	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 theh mole balance, to find the reaction rate.	2020, 2022	Junior	
	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	87%, 85%
	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 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	100%, 98%
	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	95%, 97%
	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	100%, 94%
	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				
Data are reported by semester: F2020, S2021				

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 2021**
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	88%, 100%
	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 of 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** - Course Outcome #6: Function effectively in teams to create a collaborative and inclusive environment for technical project work.	2019, 2021	Freshman	100%, 95%
	154 - Unit Operations Laboratory - Course Outcome #7: Function effectively on project teams, providing leadership to meet key objectives.	2020, 2022	Senior	
	160 - Process Design - Course Outcome #11: Function effectively on project teams by collaboratively establishing goals, planning tasks, and meeting 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 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	100%, 95%
	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				
Data are reported by semester: F2020, S2021				

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 2021, 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. *This year, due to the pandemic, it was held via Zoom and in the Spring semester; since it was via Zoom a slightly larger group of students attended.*
    ii. *The Honors Tea is each spring semester, with 10-15 chemical engineering honors students across all years of study. *In the Spring 2021 semester, the Honors Tea was held via Zoom.*
    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 47 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 third year of data collection for the new Student Outcomes. A comparison to the two previous years data is shown in Table 3 and Figure 1 below. All outcomes have strong degrees of

agreement, ranging from 77% to 87% agreement, and very low degrees of disagreement, with only 0% to 6% of respondents marking disagreement.

Outcomes 4 (recognize ethical and professional responsibilities) and **5** (function effectively on teams) were rated highest this year, with 87% of respondents agreeing they have this ability, and 4% and 6%, respectively, disagreeing that they have this ability.

Outcome 6 (design, conduct, analyze and interpret experiments) was rated lowest this year, with 77% of respondents agreeing that they have this ability, and 2% disagreeing. This rating is modestly lower than the two preceding years. **Outcome 6** is tied closely to CBE 154, the unit operations laboratory, which was online only this year due to the pandemic, and this likely impacted the results.

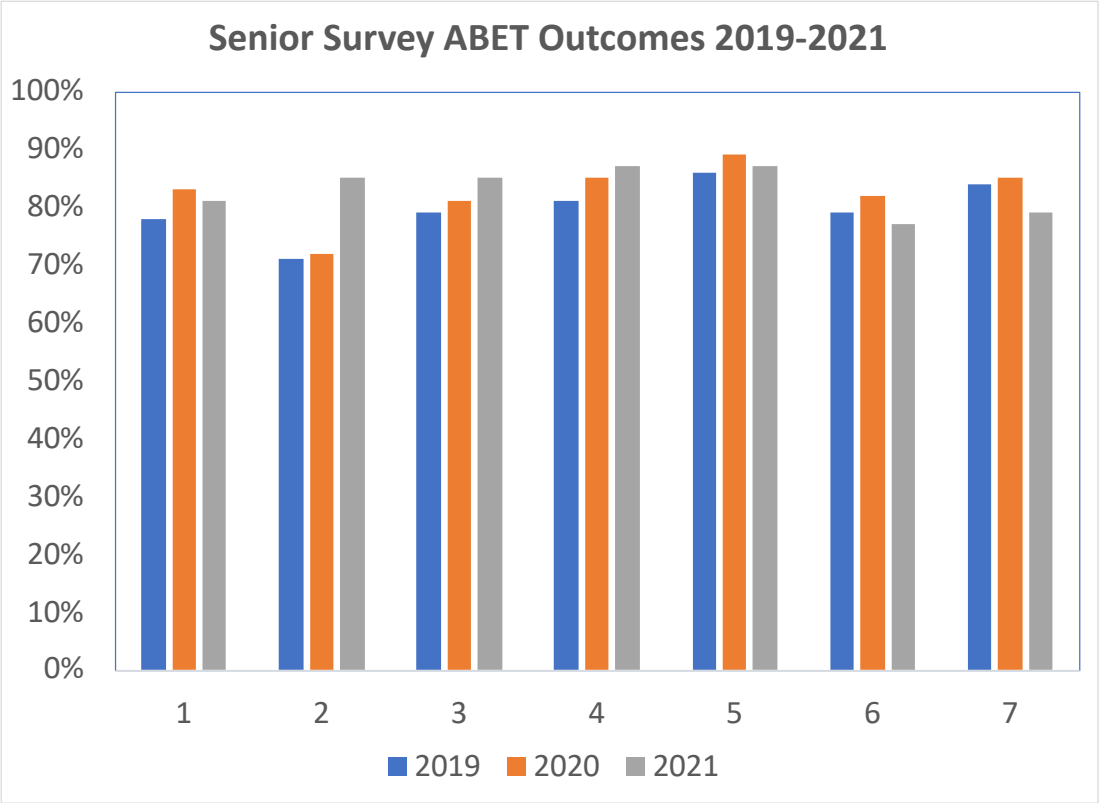
Table 2: Senior Survey Responses 2021. Students were asked if they have each ability.

College of Chemistry Exit Survey : Spring 2021 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	19%	9	81%	38	47
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%	2	11%	5	85%	40	47
3- An ability to communicate effectively with a range of audiences	2%	1	13%	6	85%	40	47
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	4%	2	9%	4	87%	40	46
5- An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives	6%	3	6%	3	87%	41	47
6- An ability to develop and conduct appropriate experimentation analyze and interpret data, and use engineering judgment to draw conclusions	2%	1	21%	10	77%	36	47
7- An ability to acquire and apply new knowledge as needed, using appropriate learning strategies	0%	0	21%	10	79%	37	47

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

Senior Survey ABET Outcomes: Comparison of 2019, 2020, and 2021							
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%
2021	81%	85%	85%	87%	87%	77%	79%

Figure 1. Comparison of Senior Survey Responses from the three years of data collection.



As can be seen in Figure 1, ratings for each Outcome 1-7 are fairly stable across the three years. **Outcome 2** (apply engineering design to produce a solution that meets specified needs), which was the lowest rated Outcome last year, shows notable improvement over the two preceding years.

Data: Student Outcomes Reflections from the AIChE Student-Faculty Focus Group, April 6, 2021:

The fall 2020 AIChE Student-Faculty Focus Group was moved to spring 2021 (April 6, 2021) due to the campus closure due to the pandemic which continued through the end of Spring 2021. The event was held online via Zoom due to the campus closure. Fifteen AIChE officers and members spanning freshman through senior year attended. Seven members of the faculty attended, including department chair Jeffrey Reimer, Director of Undergraduate Education Susan Muller, and several members of the Undergraduate Education Committee. In addition to comments on the ABET Outcomes (summarized below), the group also discussed remote learning, 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 particularly highlighted 140, 150A, 154, and 160.

Outcome 2 (apply engineering design to produce solutions): Students noted that CBE 40 and 160 do a good job on introducing this outcome. Some students indicated that they would like more exposure to design projects in 160 related to a broader range of sectors and industries (rather than focusing on petrochemical industry projects).

Outcome 3 (communicate effectively with a wide range of audiences): Students felt that they developed good communication skills particularly in 154 and 160, and noted that 40 also has a final project presentation that was helpful. Smaller group projects, e.g., in 162, were also mentioned. AIChE officers also highlighted that many AIChE sponsored activities (outreach, etc.) offer students a chance to talk to non-technical audiences.

Outcome 4 (ethical and professional responsibilities): Students indicated that these topics were well-covered in 140, in the CBE 40 design project, and in the discussions in 154 and 160. Students also noted that the first lab in MSE 45L focuses on analyzing the engineering code of ethics and a case study, and suggested this could be used in 140 also.

Outcome 5 (function effectively on a team): Students expressed confidence in their ability to function effectively on a team. They noted that 154, with the rotation of leadership roles from lab to lab and the necessity to work as a team, was especially helpful in building these skills. 160 also provided experience in teamwork, and the lectures about teamwork were highlighted as being very helpful.

Outcome 6 (design, conduct, analyze, and interpret experiments): Students noted that 154 best develops the skills in this outcome, which provides many opportunities to design and conduct experiments and analyze, interpret, and present conclusions based on their data. A few students also

noted that CBE 40 contributed to their judgement on this outcome, and a few felt that this outcome should be covered in classes across the curriculum.

Outcome 7 (aquire and apply new knowledge): Students felt the curriculum met this outcome, in Chem 4B and in 160, but saw room for improvement by including more open ended projects in courses earlier in the curriculum than 160.

Students also noted that more mental health resources are needed to support students and expressed the need for more undergraduate research and internship opportunities. Students appreciated having lectures posted online, and asked that the practice be continued once classes return to on campus.

Data: Student Outcomes Reflections from the Honors Student Tea, Monday, April 15, 2021 (via Zoom):

This year's tea was virtual due to the pandemic, but included a 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. Outcomes were discussed in smaller breakout rooms, and the full group synthesized the results and discussed other issues. Nineteen students and six faculty attended. The full list of student attendees and the breakout room 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, 150A, 150B, and 162 were helpful in contextualizing concepts into practice. 154 was also highlighted. A few students felt that Math 54 does not adequately prepare them in solving differential equations.

On **Outcome 2**, students noted that ethics is adequately covered in 154 and 160, but felt there was not enough discussion of the adverse impact of chemical industries on the environment and public health. Safety is covered well in 140, 142, 154, and 162, but economics is covered only at the end of 160 and should be introduced earlier.

Regarding **Outcome 3**, students felt they learned a lot about making good presentations in 154. More opportunities to hone written communication skills are needed; these are covered in 154 and 160 but writing assignments have been decreased in 154. A discussion of communicating to the general public is also needed.

Most students felt that they are well-educated in the area of ethical and societal impacts and professionalism (**Outcome 4**). They cited references to ethics and professional responsibilities in 140, 154, 160 and 162, and noted that the culture of Berkeley promotes sustainability and societal impacts.

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. AIChE and ChemE car also provide leadership and teamwork opportunities.

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. In addition, students found that Chem 4 and CBE 160 helped develop these skills.

When considering **Outcome 7** (acquiring and applying new knowledge), students commented that it is developed in homework sets in 150A and 141, and that 40 and 140 are also helpful in developing learning strategies.

In general, students felt that:

- the curriculum is very broad and prepares students for many opportunities
- the electives are very relevant and useful
- the CBE faculty have been very supportive this semester, making accommodations for online learning. The CBE student community is very supportive as well.
- The student to faculty ratio in CBE is too high, and CoC staff advisors are difficult to reach.
- More discussion of ethics should be included in the curriculum.
- There was some concern that CBE 140 varies significantly depending on the instructor.
- Students want greater access to undergraduate research and internships.

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.

Finally, international students pointed out that the curriculum allows them very little flexibility, as no Advanced Placement credits are available to international students. This makes it impossible for them to do a minor.

Part 3: Summary of Response to 2019-2020 Cycle

At the faculty retreat in January 2021, and at several faculty meetings in the Fall 2020 semester, the faculty discussed the data from the 2019-2020 continuous improvement cycle. During that cycle, only **Outcome 1** (identify, formulate, and solve complex engineering problems) had a measure in the "yellow" zone: a single instance from 150B with a 72% pass rate. Survey and focus group data suggested students were confident with respect to all outcomes, although in discussions some students suggested improvements in **Outcome 2** (apply engineering design to produce solutions that meet specified needs), and integration of communications (**Outcome 3**) and ethics (**Outcome 4**) throughout the curriculum. Some students also expressed concern about their math preparation.

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.

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.