Summary of ABET Student Outcomes Assessment, 2015-2016

Bachelor of Science in Chemical Engineering

Chemical and Biomolecular Engineering Department

University of California, Berkeley

June 15, 2016

Executive Summary

This report presents the direct and indirect student outcomes assessment data collected from instructors and students during the 2015-2016 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 2015-2016 academic year. Part 2 reports the indirect measures results by first reviewing the process and then presenting data from the spring 2016 graduating senior survey, and the fall 2015 and spring 2016 student focus groups (AIChE Student Lunch and Honors Student Tea). Part 3 summarizes the responses and outcomes from the 2014-2015 cycle.

Direct measures from student classwork show strong achievement of outcomes during the 2015-2016 year, and results from the senior survey show a recovery compared to 2015 data, which may have been anomalous due to a large fluctuation in response rate. Survey and focus group responses show that students continue to be confident about their skills and abilities in **Outcomes a** (apply math, science, engineering) and **b** (design and conduct experiments, analyze data). There have been improvements in **Outcomes c** (design with constraints) and **j** (contemporary issues), which may show a positive response to faculty efforts in these areas. Items that rate consistently lower in the senior survey are **Outcomes h** (broad education to understand impacts) and **j** (contemporary issues), with 66-68% of graduating seniors agreeing they have these skills. Focus group data demonstrate that students desire deeper education and opportunities in safety (**c**), ethics (**f**), impacts of engineering solutions (**h**), multidisciplinary teamwork (**d**), and co-curricular learning (**i**). Therefore, faculty discussion at the next retreat will focus on Outcomes c, d, f, h, i, and j, to generate strategies for continued improvement.

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 b is analyzed in 142 (sophomore) in 2013 and in 154 (senior) in 2014.*
   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 2015 and Spring 2016 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 2015-2016 cycle show strong student achievement of Outcomes.**

Table 1: June 8, 2016: Analysis of Outcome Assessment Templates for Student Outcomes

				% Passing						
ABET Student Outcome	**Measure from Outcome Assessment Templates**	**Year Analyzed**	**Year of Study**	**Spring 2013**	**Fall 2013**	**Spring 2014**	**Fall 2014**	**Spring 2015**	**Fall 2015**	**Spring 2016**
a- An ability to apply knowledge of mathematics, science, and engineering.	**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.	2013, 2015, …	Junior	96%				94%		
	162 - Process Dynamics and Control - Course Outcome #2: Use principles of chemistry and physics to derive mechanistic process models.	2014, 2016, …	Senior			84%				96%
b- An ability to design and conduct experiments, as well as to analyze and interpret data.	**142 - Reaction Engineering** - Course Outcome #4: Derive a reaction rate expression from a homogeneous or heterogeneous mechanism by employing most abundant surface intermediate, quasi-equilibrium, and pseudo-steady-state approximations.	2013, 2015, …	Sophomore		91%				81%	
	154 - Unit Operations Laboratory - Course Outcome #1: Set up and carry out an experimental plan for extracting information about chemical/physical processes.	2014, 2016, …	Senior			96%	100%			100%
c- An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.	**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.	2013, 2015, …	Freshman		96%				98%	
	150B - Transport and Separations - Course Outcome #4: Design a binary distillation unit with various design specifications.	2014, 2016, …	Senior				99%			
	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.	2014, 2016, …	Senior			87%	89%			90%
d- An ability to function on multi-disciplinary teams.	**40 - Intro to Chem Eng Design** - NEW item: Function effectively on project teams.	2013, 2015, …	Freshman		100%				100%	
	154 - Unit Operations Laboratory - NEW item: Function effectively on project teams.	2014, 2016, …	Senior			96%	100%			92%
	160 - Process Design - NEW item: Function effectively on project teams.	2014, 2016, …	Senior			97%	100%			91%
e- An ability to identify, formulate, and solve engineering problems.	**141 - Thermodynamics** - Course Outcome #6: Calculate equilibrium composition or conversion in a homogeneous or heterogeneous chemical reaction.	2013, 2015, …	Sophomore	70%				94%		
	150A - Transport - Course Outcome #5: Find heat transfer coefficients for forced and free convection conditions.	2015*, 2016, …	Junior					86%		92%
f- An understanding of professional and ethical responsibility.	**185 - Technical Communications** - Course Outcome #8: Recognize the ethical responsibility of engineers, and articulate morally justified solutions to ethical problems.	2013, 2015, …	Junior	96%	95%			99%	96%	
	160 - Process Design - Course Outcome # 9: Demonstrate awareness of ethical and contemporary issues related to the design and operation of chemical or biological processes.	2014, 2016, …	Senior			100%	100%			100%

Table 1 (Continued): June 8, 2016: Analysis of Outcome Assessment Templates for Student Outcomes

				% Passing						
ABET Student Outcome	**Measure from Outcome Assessment Templates**	**Year Analyzed**	**Year of Study**	**Spring 2013**	**Fall 2013**	**Spring 2014**	**Fall 2014**	**Spring 2015**	**Fall 2015**	**Spring 2016**
g- An ability to communicate effectively.	**185 - Technical Communications** - Course Outcomes #2. Write clearly, directly, and concisely in technical documents.	2013, 2015, …	Junior	94%	84%			95%	96%	
	154 - Unit Operations Laboratory - Course Outcome #6: Present technical information effectively.	2014, 2016, …	Senior			100%	100%			100%
h- The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.	**142 - Reaction Engineering** - NEW item (from Course Objectives): Analysis and awareness of reactive hazards including but not limited to hot spots and thermal runaway in packed-bed and stirred-tank reactors.	2013, 2015, …	Junior		49%				96%	
	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.	2014, 2016, …	Senior			91%	100%			100%
i- A recognition of the need for and an ability to engage in life-long learning.	**40 - Intro to Chemical Engineering Design** - NEW item: Recognize the need for and have an ability to engage in life-long learning.	2013, 2015, …	Freshman		96%				98%	
	160 - Process Design -NEW item: Recognize the need for and have an ability to engage in life-long learning.	2014, 2016, …	Senior			96%	100%			100%
j- A knowledge of contemporary issues.	**140 - Chem Process Analysis** - NEW item (from topics covered): Deconstructing chemical accidents, runaway reactors, adiabatic flames.	2013, 2015, …	Sophomore		74%				85%	
	160 - Process Design - Course Outcome #1: Discuss the principal issues in environmental protection and safety, including reactive hazards, as they relate to the design of new chemical and biological processes and retrofitting older plants.	2014, 2016, …	Senior			93%	100%			100%
k- An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	**140 - Chem Process Analysis** - Course Outcome #2: Perform steady species/element mass balances on chemical processes including multiple reactions, recycle and purge to establish overall conversion, yield, and selectivity.	2013, 2015, …	Sophomore		58%				95%	
	162 - Process Dynamics and Control - Course Outcome #1: Analytically and computationally solve ordinary differential equations.	2014, 2016, …	Senior			83%				96%

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

*Outcome sampling planned for spring 2014 has been rescheduled to 2015 due to an instructional change.

<u>Part 2: Indirect Measures: Student Survey and Focus Group</u>

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 (a-k). There were 72 responses for this year's survey. Their responses are summarized in Table 2, below. A comparison of percentage of student agreeing to each item during 2013, 2014, 2015, and 2016 is shown in Figure 1, below.

Table 2: Senior Survey Responses 2016. Students were asked if they have each ability.

Student Outcomes	Disagree		Neutral		Agree		Total
a An ability to apply knowledge of mathematics, science, and engineering	1	1%	7	10%	64	89%	72
b An ability to design and conduct experiments, as well as to analyze and interpret data	0	0%	9	13%	61	87%	70
c An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	3	4%	17	24%	52	72%	72
d An ability to function on multidisciplinary teams	3	4%	10	14%	59	82%	72
e An ability to identify, formulate, and solve engineering problems	2	3%	8	11%	62	86%	72
f An understanding of professional and ethical responsibility	4	6%	12	17%	56	78%	72
g An ability to communicate effectively	1	1%	13	18%	58	81%	72
h The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	6	8%	17	24%	49	68%	72
i A recognition of the need for, and an ability to engage in life-long learning	4	6%	9	13%	58	82%	71
j A knowledge of contemporary issues (such as energy, water, safety, and food)	6	8%	18	25%	47	66%	71
k An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	3	4%	18	25%	51	71%	72

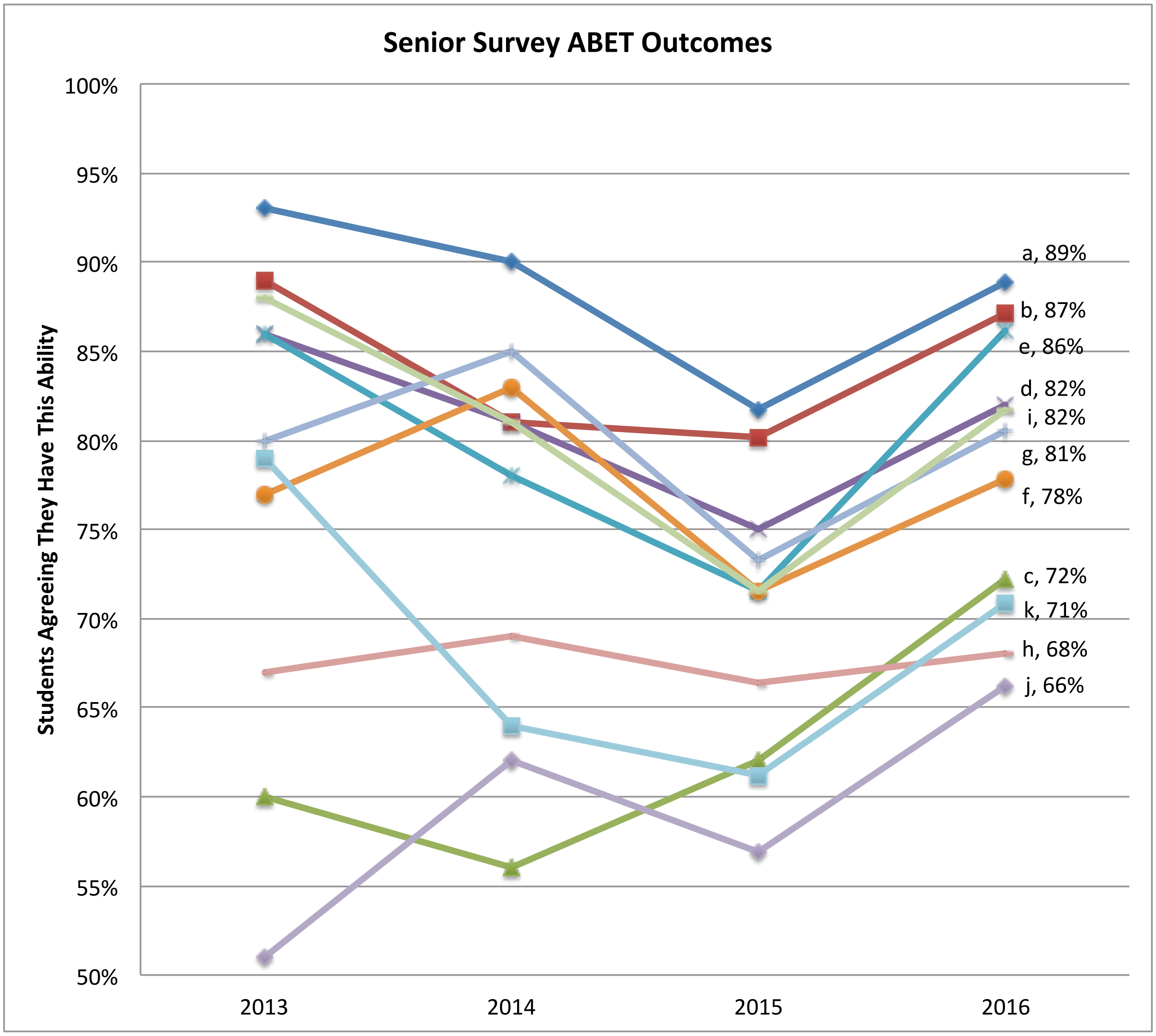

Figure 1: Comparison of Senior Survey Responses from the four years of data collection.

All items show a recovery from the 2015 levels. Because response rates for 2013, 2014, and 2016 are similar (N=70, N=80, N=72, respectively), and 2015 was unusually high (N=116), the drop in 2015 levels may have been an artifact of the change in response rate.

Outcomes a and b were rated the highest this year, and have been consistently high during the four years of surveying the senior students:

- **Outcome a** (an ability to apply knowledge of mathematics, science, and engineering; 89% agree)
- **Outcome b** (an ability to design and conduct experiments, as well as to interpret experimental data; 87% agree)

There is a modest upward trend in two of the Outcomes that have received extra attention for improvement in the past few years: Outcome c and Outcome j. This is especially encouraging given the emphasis on incorporating realistic constraints into the freshman and senior design courses, and the emphasis on tying in contemporary topics and events into undergraduate teaching. Effort will continue to keep these skills increasing. The four-year trend on senior students agreeing that they have these skills:

- **Outcome c** (an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health, and safety, manufacturability, and sustainability)
    - 60%, 56%, 62%, 72%
- **Outcome j** (a knowledge of contemporary issues)
    - 51%, 62%, 57%, 66%

The Outcomes with the lowest percentage of students agreeing have consistently been among the lowest rated during the past four years of data collection:

- **Outcome h** (the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context; 68% agree; 8% disagree)
- **Outcome j** (a knowledge of contemporary issues; 66% agree; 8% disagree)

Data: Student Outcomes Reflections from the AIChE Student Lunch, November 18, 2015:

For this year's lunch, student representatives volunteered with specific issues they wished to discuss. Ethics, course load, biology emphasis, opportunities for applications and hands-on work, diversity of faculty teachers, social integration of transfer students, frequency of course offerings, and interest in courses in computation and process safety were the issues the students brought to the discussion. Students also reflected directly on the Student Outcomes a-k. Points relating to the Student Outcomes a-k are the following:

- **Outcome a (ability to apply knowledge of mathematics, science, engineering**): This is done well in the curriculum, beginning at the freshman level and continuing.
- **Outcome c (ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability):** Students are interested in more safety training, and suggest it can be tied in with ethics training.
- **Outcome d (ability to work on multidisciplinary teams**): Students note that teamwork is required, but that there aren't many opportunities to do teamwork with students from other disciplines, such as with bioengineers.
- **Outcome e (ability to identify, formulate, and solve engineering problems):** This is done very well, beginning at the freshman level.
- **Outcome f (understanding of professional and ethical responsibility):** Technical communications 185 is the main place students get this training now, but students would like to see ethics emphasized more in the curriculum. Student suggestions included requiring an engineering ethics course or introducing ethics in 140, perhaps using discussion time.

- **Outcome h (broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context):** Project work, such as that in 40, is good at getting students to begin considering social and economic impacts of their engineering solutions. Students felt that the curriculum should push for deeper considerations of impacts to community and biodiversity, and more project options. They want to be forced to think deeply and reckon with these issues, treat them quantitatively and in depth, and learn something more in the process.
- **Outcome k (ability to use techniques, skills, and modern engineering tools necessary for engineering practice):** Students focused on the software aspect of this. Students love the opportunity of the new computation course (143) to learn ASPEN, and suggest it be offered early in the curriculum, such as the same semester as 140.

Data: Student Outcomes Reflections from the Honors Student Tea, Tuesday, April 26, 2016:

This year's tea invited students to self-assemble around discussion prompts ranging from desired new courses, general areas for improvement, to specific questions about the curriculum. One group addressed the Student Outcomes a-k specifically, and each group reported a summary. Please note that the group who assembled around the Student Outcomes prompt happened to be all freshmen students, which has limitations, but also provides a complimentary perspective to that of the Senior Survey and AIChE Lunch reported above.

Discussion Prompt:

ABET Student Outcomes: Is your curriculum doing a particularly good or bad job of helping you achieve these outcomes? Which ones, and in what ways?

This group felt the Outcomes were met very well through the curriculum, especially the following:

- **Outcome a** (an ability to apply knowledge of mathematics, science, and engineering)
  - E7 data analysis and numerical methods, using MATLAB for Chem 4B and E45 build this skill
- **Outcome b** (an ability to design and conduct experiments, as well as to analyze and interpret data)
  - Chem 4B does this well
- **Outcome c** (an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability)
  - Chemical Engineering 40 group project develops this ability
- **Outcome e** (an ability to identify, formulate, and solve engineering problems)
- **Outcome f** (an understanding of professional and ethical responsibility)
  - Significant exposure to green chemistry principles in chemistry courses does this
- **Outcome g** (an ability to communicate effectively)

    - This is developed through lab reports and elevator pitches in Chemical Engineering 40
- **Outcome h** (the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context)
    - Final projects in Chemical Engineering 40 develop this
- **Outcome j** (a knowledge of contemporary issues)
    - This is developed through the new Energy Journal Club, and the American Cultures requirement in the curriculum
- **Outcome k** (an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice)
    - E7 develops these skills

Students suggested improvement in these areas:

- **Outcome d** (an ability to function on multidisciplinary teams)
    - More effort or opportunity for CBE students to work with students of other majors
- **Outcome i** (a recognition of the need for, and an ability to engage in life-long learning)
    - Make resources such as seminars and decals more publicized

<u>Part 3: Summary of Response to 2014-2015 Cycle</u>

The 2014-2015 continuous improvement cycle identified Outcomes c (design with constraints), (contemporary issues), and (teams) for discussion based on direct and indirect measures. The faculty met on July 24, 2015 at the annual Faculty Retreat to discuss and address these.

Faculty response to Student Outcomes assessment results, July 24, 2015 Faculty Retreat:

The students' self-assessment of design with constraints seems fairly accurate compared to faculty experience of students' skills. We want students to be confident to solve open-ended problems and do design.

An action item is to assemble a focus group of students to discuss the survey results further.

In an effort to bring contemporary issues to undergraduate students, and to promote life-long learning, we are taking up two specific action items: 1) Faculty teams brainstormed contemporary issues and research topics that relate to course teaching at the conclusion of this retreat. 2) In order to make seminars and colloquia accessible to undergraduate students, the DUE will invite undergraduates to the GSAC seminar, and will work with Carlet and the GSAC to propose that graduate students seeking extra teaching/presentation experience give talks on their research, a technology, or a paper targeted to the undergraduate audience. These seminars will be advertised directly to UGrads and through AIChE student group.

We discussed multidisciplinary teams at some length. There have been no changes in the way the curriculum requires teaming during the past three years, so a decrease in student self-assessment is likely due to shifting student perceptions. Several faculty members affirmed that the spirit of the outcome is for students to practice teaming among multiple disciplines. We agree with students that several required (but not core CBE) courses do include multidisciplinary teams, including E45, Chem 4B. We value teamwork in general, and several core courses always require teamwork, including 40, 154, 160, 185, and frequently others. We discussed intercultural competency as a skill to be learned and applied within a multidisciplinary team environment. We also discussed student preferences for self-assembly of teams, and the ways that this prevents the broader practice of teamwork skills, and negatively impacts those students such as transfers, international students, or minorities who may be excluded from groups that form as early as students' first year.