

5. PROGRAM EFFECTIVENESS – OUTCOMES ASSESSMENT

5.1 Outcomes Assessment Procedures

Program assessment is conducted quite thoroughly at the undergraduate level due to ABET accreditation requirements. Such data are not as easily available for the graduate program, however, making assessment of the graduate program less comprehensive. One reason for this gap in data has been the high turnover of graduate advisors since 2010. Where once all data collection and maintenance was the sole responsibility of the Director of Graduate Studies, the Graduate Academic Advisor position has slowly evolved to take on more of this task. However, due to the high turnover in this position, data maintenance has not been consistent and some data have even been permanently lost.

Therefore, the Department feels it is necessary to secure more stability in the Graduate Academic Advisor position, in addition to putting into place practices and means that will ensure the preservation of graduate program data, thus allowing for a graduate outcomes assessment. One possible solution to the stability issue is to hire an individual into the Graduate Academic Advisor position as a career-line faculty member. That approach is currently being assessed. Of particular interest, are data and trends relating to women and ethnic minorities, especially given the new recruitment efforts the department has started for these groups. Those data are available from OBIA, as shown in Table 3.2. Internal tracking of graduate student progress is also being upgraded. Recently, the College has developed a graduate online student tracking tool that we are tailoring for mechanical engineering. This tool will enable a more proactive approach to graduate student advising by 1) reminding students of program expectations (qualifying exam, proposal defense, etc.) and 2) verifying that milestones have been satisfied. Time to degree will also be monitored using the new tool. Most recently, we have noticed several graduate students who have exceeded the PhD time limit (7 years).

What follows relates primarily to the undergraduate program, but information on the graduate program will be included where graduate data is available and relevant.

5.1.1 Student Information

5.1.1.1 Undergraduate

As mentioned above, extensive data collection and assessment occurs at the under-graduate level in order to maintain ABET accreditation. Please refer to Appendix A for further details.

5.1.1.2 Graduate

As can be seen in the Graduate Degree Completion/Attrition Data table in Section 5.3, our graduate program has grown, from 189 students at the time of the last review to 218 active students. As reported in Section 6.1.3, the graduate student population has changed from 31% PhD students in 2010 to 54% PhD students on 2017. Our retention rate has remained fairly steady, with an

average of 8% of students/year dropping out of the program. Time to degree is higher than desired. This metric is adversely affected by students who leave near the end of their studies for local employment, which extends the time to complete their thesis/dissertation.

5.1.2 End of Program Assessment

5.1.2.1 Undergraduate

Extensive end-of-program assessment is conducted with our undergraduates. Passing the Fundamentals of Engineering (FE) exam was a requirement for graduation from the Department until the fall semester of 2015. Currently, the department does not require students to take the FE exam, similar to most ME programs nationwide. The FE exam was offered twice per year (Fall – in October and Spring – in April); however, recently it was changed to an online format so students may take the test when they wish. Recalling that passing the FE Exam was a graduation requirement, our graduates had an effective 100% pass rate until Fall 2015. Of course, our students might not have passed on their first attempt. The generally 80-90% pass rate in Fig. 5.1 merely represents a given attempt. No FE data in the plot’s “gap” were available when this report was prepared. As shown in Fig. 5.1, the single-attempt pass rate for University of Utah ME students was slightly above the national average (with variability in data resulting from statistically small samples – i.e., fewer students taking the exam). Our students often elected to take the exam during the Spring semester of their junior year such that they could retake the exam (if necessary) during their senior year. This choice undoubtedly affected the level of preparation for the exam, possibly bringing down the overall pass rate. In other words, filtering the data to show pass rates for only seniors would likely show an even more favorable gap between Utah students and the national average. Ultimately, for the years shown in Fig. 5.1 our students were required to pass the exam as a graduation requirement, thus far outflanking the national average.

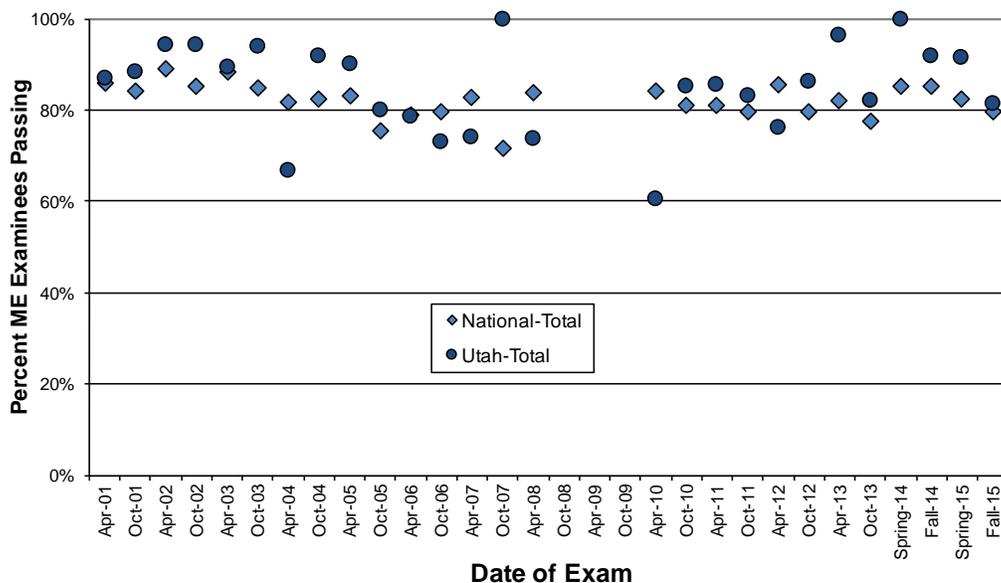


Fig. 5.1 Pass rate of students taking the Fundamentals of Engineering (FE) Exam

For the FE exam, the “trigger” prompting continuous-improvement action would be the occurrence of a noticeable dip in scores, which clearly has not happened recently. A dip in scores triggers investigation only if the number of students taking the exam is large enough to be statistically significant, in which case, the exam results would be examined in greater detail (by topic area) to identify the reason for the dip. Since the degree requirement of an FE exam pass was removed, the number of students taking the exam has dropped significantly.

Another end-of-program assessment occurs within our curriculum. The undergraduate program culminates with the capstone design experience, or Senior Design. The Senior Design sequence begins with ME EN 3000 Design of Mechanical Elements in the 3rd year, and continues with ME EN 4000/4010 Engineering Design I/II in the 4th year. In ME EN 3000, students learn to design mechanical elements by applying failure analysis and reliability requirements. In ME EN 4000/4010, students work in teams of typically 4-5 students to apply design methodology to a specific project, which is often industry- or faculty-sponsored, or may be part of a national student design competition. Several important components of the capstone design experience include identifying and formulating problems, presentations of economic considerations, machine design, and the design process. In most cases, the outcome of the Senior Design sequence is a fully-functional prototype that is showcased to the public on Design Day at the end of spring semester.

As Senior Design represents a capstone experience, the level of achievement related to undergraduate program outcomes may be assessed at the end of the course sequence. For example, at the department’s “Design Day” held in December and April at the end of the fall and spring semesters, respectively, students exhibit their senior projects and provide poster presentations. A team of ME faculty members is typically tasked to provide a direct assessment of several ABET outcomes associated with the capstone design experience. The faculty assessors visit with each design team, and provide an assessment of the degree to which the design project involves/demonstrates designing and conducting experiments. Results from this type of assessment, as well as others in Senior Design relating to topics such as oral/written communication, are provided in Appendix A.

Another assessment of outcomes for our undergraduate program is the subject pass rate for University of Utah BS graduates on the Mechanical Engineering PhD qualifying exam during the period 2009-2015, as shown in Table 5.1. While these students constitute a small subset of the program’s graduates, their performance nevertheless suggests that Design and Linear Algebra need attention in the curriculum.

Table 5.1 Subject Pass Rate for BS Alumni in Mechanical Engineering PhD Qualifier

Subject	Total	Passed 1st Attempt	1st Attmp Pass Rate	Passed 2nd Attempt	2nd Attmp Pass Rate	Overall Pass Rate
<i>Biomechanics</i>	3	2	67%	1	33%	100%
<i>Calc. and Diff. Equations</i>	1	1	100%	0	0%	100%
<i>Composite Materials</i>	4	4	100%	0	0%	100%
<i>Controls</i>	6	5	83%	1	17%	100%
<i>Design</i>	4	3	75%	0	0%	75%
<i>Dyanamics</i>	2	2	100%	0	0%	100%
<i>Ergonomics</i>	3	3	100%	0	0%	100%
<i>Finite Element Methods</i>	1	1	100%	0	0%	100%
<i>Fluid Mechanics</i>	6	6	100%	0	0%	100%
<i>Functional Anatomy</i>	1	1	100%	0	0%	100%
<i>Heat Transfer</i>	4	4	100%	0	0%	100%
<i>Linear Algebra</i>	7	5	71%	1	14%	86%
<i>Manufacturing</i>	1	1	100%	0	0%	100%
<i>Materials Engineering</i>	3	3	100%	0	0%	100%
<i>Numerical Methods</i>	3	3	100%	0	0%	100%
<i>Robotics</i>	4	3	75%	1	25%	100%
<i>Statistics</i>	4	3	75%	1	25%	100%
<i>Strength of Materials</i>	11	9	82%	2	18%	100%
<i>Sust. Energy Engineering</i>	1	1	100%	0	0%	100%
<i>System Dynamics</i>	1	1	100%	0	0%	100%
<i>Thermodynamics</i>	4	4	100%	0	0%	100%
<i>Vibrations</i>	1	0	0%	1	100%	100%
TOTAL	75	65	87%	8	11%	97%

5.1.2.2 Graduate

Every graduate student must complete a “culmination event” in order to graduate. For MS thesis students and PhD candidates, this event is the research defense. The defense begins as a presentation of the student’s original research, which is open to the public. After a public question-and-answer session, a closed question-and-answer session begins. Only the student and his or her committee are present for the closed session. During this period, the student is given a thorough examination in the methods of the research, the existing literature in the area, the results obtained, and the conclusions drawn. Questions pertaining to background subject knowledge, as applicable to the research, may also be asked. At the end of the defense, if the student passes, the content of the manuscript will have been vetted for publication. In some cases, students may have to refine their manuscript before taking it to the thesis editor for publication. This measure of “quality control” ensures that the state of research in the department remains of high caliber.

For non-thesis students, who often do no research for their degree, a different kind of culmination event is in place. The non-thesis MS degree has been designed to provide analytical depth in graduate study, so a comprehensive final exam serves this purpose best. Non-thesis students must pick an area of focus, which might fall within one of the four department research groups, or might straddle one or more of these groups. The MS Non-Thesis (MSNT)

comprehensive final exam, which must be successfully passed to obtain the MS degree in the Department of Mechanical Engineering (non-thesis track), is described on pages 10-11 of the Graduate Handbook, which is included in Appendix O.

5.1.3 Alumni Satisfaction

Alumni satisfaction is measured and evaluated through our ABET accreditation. We offer an exit survey to our graduating students, data of which is analyzed annually. We also send out an alumni survey every year. Further information on this process can be found in our ABET document and in Appendix A of this document.

5.2 Outcomes Assessment Feedback

Detailed analyses of how the assessment activities have improved teaching and learning is the centerpiece of our ABET report. Relevant excerpts of that report have been included in Appendix A for the convenience of this review. The entire ABET document is available upon request.

5.3 Degree Completion Data

Below are degree completion/attrition data. Figure 5.2 contains data on the Department's degree production since the year 2000, which has been steadily increasing for the B.S. degree. The department is expecting over 170 B.S. degree graduates in 2016-17, which would represent a 35% increase since the previous review. M.S. degree production peaked in the years following the national economic downturn in 2008-2009. Ph.D. degree production is expected to increase in the upcoming years as the number of research active faculty has grown, and will continue to grow, as shown in Fig. 2.1. Similarly, the number of enrolled Ph.D. students has more than doubled since 2010. Table 5.2 shows our graduation and attrition data for the graduate program. As reported previously, recordkeeping the Graduate Advising Office has been spotty due to excessive turnover. In some cases, data in Table 5.2 may be based on best estimates.

Degree Production

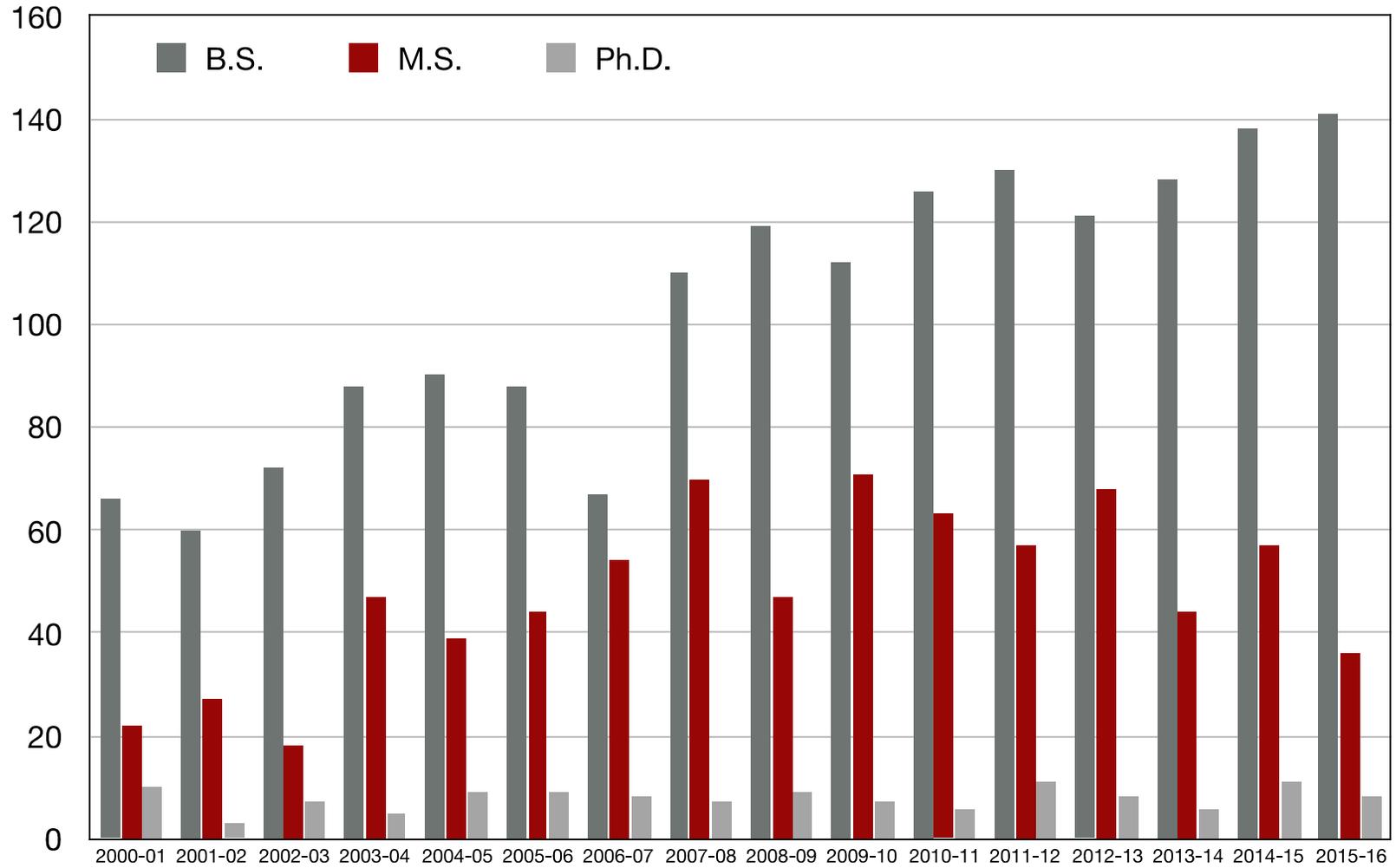


Table 5.2 Graduate Degree Completion/Attrition Data, 2007-2017

Academic Year	# of students entering	# of students entering with BS	# of students entering with Masters	# who left before completing Masters	# who left after completing Masters	# who completed PhD	Average time to complete Masters	Average time to complete PhD	# of students remaining in program
2007-2008	66	58	8	17	70	7	2.5	9.9	180
2008-2009	49	40	9	20	47	9	2.4	6.5	201
2009-2010	57	49	8	16	71	7	2.9	7.7	192
2010-2011	58	49	9	18	63	6	3.5	6.0	189
2011-2012	65	47	18	10	57	11	2.8	7.1	187
2012-2013	63	49	14	6	68	8	2.9	6.3	188
2013-2014	62	48	15	15	44	6	2.7	6.9	185
2014-2015	62	48	15	22	57	11	2.9	5.4	157
2015-2016	71	45	26	14	36	8	2.9	5.0	180
2016-2017	70	46	24	15	44	10	2.7	6.3	218

5.4 Employment

As described above, record keeping in the graduate program has been spotty due to inconsistencies and high turnover in the Graduate Academic Advisor position. This problem also means that limited data have been collected on graduate student alumni. In addition to providing data collection and maintenance procedures for the Graduate Academic Advisor, a system for contacting alumni should be established. This system could be modeled after the undergraduate program's system of alumni surveys and interviews. A wealth of online survey tools is now available which could help in gathering these data. This is going to be one of the important tasks for the Graduate Committee to resolve in the near future.

5.4.1 Employment - Demand

The demand for mechanical engineers is projected to remain high for at least the next seven years both nationally and in Utah. Table 5.3 presents occupation projections extracted from over 800 categories provided by the U.S. Department of Labor, Bureau of Labor Statistics, Occupation Employment Statistics (OES). These occupations are those most closely related to engineering and computer science. Mechanical Engineering jobs are projected to grow at a rate of 200/year (3rd highest on the list) for the period from 2014 – 2024. When all of the jobs related to Computing are added together, that particular general discipline is projected to have the highest demand. On the other hand, job projections for Industrial Engineering and Aerospace Engineering should be added to those for Mechanical Engineering as these jobs are traditionally filled in Utah by mechanical engineers. Note that there are no degree programs in Industrial Engineering in Utah. Considering these combined categories, Mechanical Engineering demand in Utah (340/year) is projected to be second to only that for Computing through 2024.

Table 5.3 Engineering and Computer Science Related Occupation Projections Between 2014 (base year) and 2024 (projection year) for Utah. Projections Central: State Occupational Projections, Long Term Projections (through 2024) accessed at <http://www.projectionscentral.com>.

Occupation Code	Occupation Name	Base	Projection	Change	Change %	Avg Openings Per Year
15-1132	Software Developers, Applications	8840	14040	5200	58.7	640
15-1121	Computer Systems Analysts	3820	5710	1890	49.5	240
17-2141	Mechanical Engineers	3210	4240	1030	32.2	200
15-1142	Network and Computer Systems Administrators	3790	5140	1350	35.5	180
17-2051	Civil Engineers	3150	4090	940	29.7	180
11-3021	Computer and Information Systems Mngrs	3080	4470	1390	45.1	170
15-1133	Software Developers, Systems Software	3050	4360	1310	42.7	170
15-1131	Computer Programmers	3700	4480	780	21.2	170
15-1134	Web Developers	2120	3290	1170	55.2	140
15-1199	Computer Occupations, All Other	2660	3530	870	32.8	120
17-2112	Industrial Engineers	1840	2440	600	32.8	110
15-1152	Computer Network Support Specialists	1620	2200	580	35.9	80
17-2072	Electronics Engineers, Except Computer	1830	2210	380	20.9	80
17-3023	Electrical and Electronics Eng Technicians	1480	1760	280	19.1	70
17-2071	Electrical Engineers	1460	1790	330	22.7	60
15-1141	Database Administrators	920	1270	350	38	50
17-2031	Biomedical Engineers	440	730	290	68	40
15-1143	Computer Network Architects	800	1120	320	39.7	40
17-2131	Materials Engineers	400	540	140	33.6	30
17-2199	Engineers, All Other	580	730	150	25.8	30
17-2011	Aerospace Engineers	600	740	140	22.5	30
17-2081	Environmental Engineers	380	480	100	24	20
17-2041	Chemical Engineers	310	370	60	19.5	10
17-2171	Petroleum Engineers	250	290	40	17.7	10

5.4.2 Employment - University of Utah Mechanical Engineering Graduates

Appendix X contains a report provided by the Career & Professional Development Center (formerly Career Services) to the Dean of the College of Engineering on February 2017 in regards to August 2015 through May 2016 graduates within the College. The report indicates that of students who planned to graduate and obtain full time employment, approximately 66% of undergraduate engineering students and 80% of graduate engineering students had been hired by a company at the time of the survey. Of those who planned to attend graduate school, approximately 68% of undergraduates and 81% of graduate students had been admitted to a graduate program. About 73% of Mechanical Engineering students (undergraduate and graduate) had been hired by the time of the survey at an average starting salary of about \$59,000 (undergraduate) and \$70,000 (graduate). Top employers of Mechanical Engineering graduates include Hill Air Force Base, Northrop Grumman, L3 Communications, IM Flash Technologies, and Orbital ATK. Details on place of employment for mechanical engineering graduates from 2012-2016 are available at the [Career and Professional Development Center](#).

Some conclusions can be drawn about the data covering the period from May 2012 through May 2016 that is available at the Career and Professional Development Center website. First, the

number of graduate respondents is low: only 63 MS and 10 PhD degree recipients provided information on their place of employment following graduation. At the BS level, only 26% of the 525 degree recipients did the same. Second, the percentage of graduates who remain in-state for employment is quite high; 77% for undergraduates and 73% for graduates. These rates represent a double-edged sword. On the one hand, they indicate that our students are finding employment locally, which is a good for the state economy and helps to publicize our program across the state. However, they also indicate that only about 1/4 of our graduates are leaving the state for work, resulting in reduced opportunities to increase the recognition of our program nationally. Graduate degree recipients who responded to the survey were overwhelmingly at the MS level (63-MS, 10-PhD). As many of our MS students are pursuing a non-thesis track and working in local industry, it is understandable that most of these degree recipients would remain in the Salt Lake City area.

Employment information for PhD degree recipients covering a two-year period between Spring 2015 and Fall 2016 is presented in Table 5.4. For this group of 20, 20% went into academia, 15% went to a national lab, 15% were employed by a DoD Lab, and the remaining 50% took jobs in industry.

Table 5.4 Employment Details for PhD Recipients from 2015-2016

Degree	Employer	Position Description
Spring 2015	Lawrence Livermore National Laboratory	Scientist
Spring 2015	Oculus VR	Mechanical Engineering Researcher
Spring 2015	Gray Matter Research	Mechanical Design Engineer
Spring 2015	Wasatch Autonomy, Inc.	Lead Mechanical Engineer
Summer 2015	Sandia National Laboratories	Member of the Technical Staff
Summer 2015	Fresenius Medical Care	R&D Engineer
Summer 2015	University of California, Davis	Tenure-track Assistant Professor
Summer 2015	United States Air Force	System Design Engineer
Fall 2015	Energid Technologies	Senior Research Engineer
Fall 2015	Iranian surgical robotics company	Scientist
Spring 2016	U.S. Naval Research Laboratory	Postdoctoral Research Fellow
Spring 2016	Intermountain Healthcare	Senior Biomechanical Engineer
Spring 2016	Microsoft	Applied Scientist II
Summer 2016	University of Maine	Tenure-track Assistant Professor
Summer 2016	Intel Corporation	Process Engineer
Summer 2016	University of Maine	Tenure-track Assistant Professor
Summer 2016	Omron Adept Technologies	Sr. Mobile Robot Software Engineer
Fall 2016	Weber State University	Tenure-track Assistant Professor
Fall 2016	United States Air Force	Unknown
Fall 2016	Lawrence Livermore National Laboratory	Postdoctoral Research Staff

Appendix A

Outcomes Assessment

[1]. CRITERION 3. STUDENT OUTCOMES

A. Student Outcomes

The following fifteen Student Outcomes are published at

- The department website <http://mech.utah.edu/academics/undergraduate/>, as well as
- The University of Utah General Catalog: <http://learningoutcomes.utah.edu/degree/93>.

Prior to graduation, each student in the University of Utah Mechanical Engineering Bachelor of Science Program will demonstrate:

1. A background and depth in mathematical, scientific and engineering principles sufficient to apply this knowledge to mechanical engineering problems.
2. The ability to design and conduct experiments and subsequently analyze the resulting data for design or other engineering purposes.
3. The ability to design a mechanical engineering system, component, or process for achieving a desired goal.
4. The ability to use teamwork in pursuit of a multidisciplinary goal.
5. An ability to identify, formulate, and solve mechanical engineering problems.
6. An understanding of the professional and ethical responsibilities of a mechanical engineer.
7. The ability to effectively communicate technical information in written reports and memos.
8. The ability to effectively communicate technical information in oral presentations.
9. The broad education to understand the impact of mechanical engineering solutions in a global and societal context.
10. An understanding of the need for, and the ability to remain current in, engineering practices through lifelong learning.
11. A knowledge of contemporary issues impacting engineering.
12. Competency in the application of techniques and skills necessary for mechanical engineering practice.
13. Competency in the application of modern computer-based tools for solving engineering problems.
14. Participation in a capstone design project and optional participation in faculty-led research, cooperative internships, industrial design projects, and independent study projects.
15. An ability to work professionally in thermal or mechanical systems, with knowledge of each area.

Relationship of Student Outcomes to ABET a-k Requirements

Table 3A-1 illustrates how the ABET a-k requirements are accounted for by the 15 Student Outcomes. Note that Student Outcome 15 is in addition to the ABET requirements.

Table 3A-1: Mapping of Student Outcomes to ABET a-k Requirements

ABET a-k Requirement		Student Outcome(s)	
a.	"...an ability to apply knowledge of mathematics, science, and engineering"	1.	"A background and depth in mathematical, scientific and engineering principles sufficient to apply this knowledge to mechanical engineering problems"
b.	"...an ability to design and conduct experiments, as well as to analyze and interpret data"	2.	"The ability to design and conduct experiments and subsequently analyze the resulting data for design or other engineering purposes"
c.	"...an ability to design a system, component, or process to meet desired needs"	3.	"The ability to design a mechanical engineering system, component, or process for achieving a desired goal"
d.	"...an ability to function on multi-disciplinary teams"	4.	"The ability to use teamwork in pursuit of a multidisciplinary goal"
e.	"...an ability to identify, formulate, and solve engineering problems"	5.	"An ability to identify, formulate, and solve mechanical engineering problems"
f.	"...an understanding of professional and ethical responsibility"	6.	"An understanding of the professional and ethical responsibilities of a mechanical engineer"
g.	"...an ability to communicate effectively "	7.	"The ability to effectively communicate technical information in written reports and memos"
		8.	"The ability to effectively communicate technical information in oral presentations"
h.	"...the broad education necessary to understand the impact of engineering solutions in a global and societal context"	9.	"The broad education to understand the impact of mechanical engineering solutions in a global and societal context"
i.	"...a recognition of the need for , and an ability to engage in life-long learning"	10.	"An understanding of the need for, and the ability to remain current in engineering practices through lifelong learning"
j.	"...a knowledge of contemporary issues"	11.	"A knowledge of contemporary issues impacting engineering"
k.	"...an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice"	12.	"Competency in the application of techniques and skills necessary for mechanical engineering practice"
		13.	"Competency in the application of modern computer-based tools for solving engineering problems"
-	No specific ABET outcome requirement; this supplemental outcome requires <i>synthesis</i> of the above a-k outcomes by the time of graduation.	14.	Participation in a capstone design project and optional participation in faculty-led research, cooperative internships, industrial design projects, and independent study projects.
-	No specific ABET outcome requirement; this supplemental outcome addresses program-specific outcomes in Criterion 9	15.	"An ability to work professionally in thermal or mechanical systems, with knowledge of each area."

In addition to ABET a-k requirements, graduates from an ABET-accredited Mechanical Engineering program must be able to "... apply principles of engineering, basic science, and mathematics (including multivariate calculus and differential equations); to model, analyze, design, and realize physical systems, components or processes; and prepare students to work professionally in either thermal or mechanical systems while requiring topics in each area." This program-specific ABET requirement (discussed in depth under criterion 9) maps to Student Outcomes #1, 2, 3, 4, 5, 6, 7, 8, 12, 13, 14, and the new outcome 15 to address the thermal aspect explicitly.

Process for defining and periodically reviewing student outcomes

The process for assessing *attainment* of student outcomes is described separately in Criterion 4: Continuous Improvement. This section limits its scope to how the outcomes are defined and approved. As seen in the (preceding) Table 3A-1, the outcomes track closely with ABET's a-k, with the primary differences being more granularity in outcomes "g" and "k" and addition of two outcomes, one to focus on *synthesis* of learned skills in a capstone design experience, and another to ensure assessment of specific skills expected of Mechanical Engineers under ABET's Criterion 9. The split of ABET's outcome "g" (communication) to become our outcomes 7 (writing) and 8 (presenting) facilitates focusing attention on these different forms of communication separately. Separate tracking of achievement in written and oral communication is partially motivated by student exit interviews that indicate effectiveness of instruction in writing and presenting are not on a par with each other (see Criterion 4 for further details). ABET's outcome "k" has been likewise split into our outcomes 12 and 13 for similar reasons.

The program constituencies are regularly engaged to review student outcomes. In this review cycle, in particular, such review was essential to ensure unanimous approval of the new 15th student outcome. For example, the August 21, 2014, faculty retreat meeting minutes reports that students participating in the Spring 2014 exit interviews unanimously favoring the addition of a 15th outcome to specifically refer to thermal (and fluid) systems. A straw man vote was taken at the retreat with the faculty tabling the motion [to officially add the 15th outcome]. Adding the 15th outcome became a faculty meeting agenda item on October 7, 2014. It passed unanimously after it was explained that this outcome will provide a stronger impetus under Criterion 4 (Continuous Improvement) to ensure that that our students attain knowledge of thermal and mechanical systems with an ability to work professionally in at least one of those areas (as required in the program-specific Criterion 9). Whereas students are asked to review outcomes approximately 4 times per year (in junior seminar courses and senior exit interviews), faculty review the outcomes once per year in the Annual Retreat with follow-up review in faculty meetings as needed, and industry constituencies review student outcomes once per ABET review cycle, with the most recent review having been in May of 2015. At the beginning of Fall semester 2013, the Curriculum Committee carefully evaluated the extent to which the current curriculum fosters achievement of outcomes. Such an assessment was crucial in the wake of several major curriculum revisions (see Criterion 4 Sec. B: Continuous Improvement). This activity was an example of an extra "as needed" review beyond regularly scheduled ones.

Relationship of Courses in the Curriculum to the Student Outcomes

The Student Outcomes are coupled to specific course outcomes for purposes of assessment. In Fall 2014, this process was formalized by assigning 2-3 person teams to evaluate course content and assessment twice per review cycle. Part of this review entails determining values for the following descriptors used to assess the activity level for each outcome:

- 0 No activity
- 1 Low level, sometimes, to a limited degree
- 2 High level, often, essential component

Table 3B-2 shows the current relationships between the Student Outcomes and Mechanical Engineering courses. The course-review teams are ultimately responsible to update Table 3B-2 at least once per review cycle, but the table might be updated more frequently by other groups (such as the Curriculum committee) as needed. As a result, this table has been updated continually since its original development in the previous review cycle. From this table, it is clear that each of the Student Outcomes is supported by several Mechanical Engineering courses. Whereas the table lists only Mechanical Engineering courses, the Mechanical Engineering curriculum relies on external supporting departments to contribute further to Student Outcomes. After updating the course activity level table, the same faculty members are asked to review and revise the course objectives (found in the syllabi listed at the end of this Self Study) to ensure consistency among all instructors' lesson plans and to identify any opportunities for improvement identified through Course Outcome assessment of sample student work, and various other direct and indirect assessment data sets.

Table 3B-2: Relationship Between Program Outcomes and ME Course Outcomes

Course #	Course Name	Program Outcome Number														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15*
1000	Introduction to Mechanical Design for Engineering Systems	1	1	2	2	1	1	2	2	1	1	1	2	2	0	0
1005	Computer Aided Design Laboratory	1	1	2	0	1	0	1	0	0	0	1	1	2	0	0
1010	Computer-Based Problem Solving for Engineering Systems	2	2	2	2	2	0	1	0	0	0	0	2	2	0	2
1300	Statics and Strengths of Materials	2	0	1	1	2	1	0	0	0	1	1	2	1	0	2
2020	Particle Dynamics	1	0	0	1	2	1	1	0	0	1	1	2	2	0	2
2080	Dynamics	2	0	0	1	2	1	1	0	0	1	1	2	2	0	2
2300	Thermodynamics I	2	0	1	0	2	0	0	0	0	0	1	2	0	0	1
2450	Numerical Methods for Engineering Systems	2	1	1	1	2	0	1	0	0	0	0	2	2	0	1
2650	Manufacturing for Engineering Systems	1	0	2	2	2	1	2	0	1	1	2	2	1	0	1
3000	Design of Mechanical Elements	2	0	2	0	2	1	1	0	1	1	1	2	2	0	2
3200	Mechatronics I: Modeling, Actuators, and Data Collection	2	2	2	2	2	0	2	1	0	1	0	2	2	0	2
3210	Mechatronics II: Mechanical Components and Control Systems	2	2	2	2	2	1	2	1	0	1	0	2	2	0	2
3300	Strength of Materials	2	2	1	2	2	0	2	0	0	0	0	2	1	0	2
3600	Thermodynamics II	2	2	1	1	2	1	2	0	1	1	1	2	1	0	2
3650	Heat Transfer	2	2	1	0	2	1	2	0	1	0	1	2	2	0	2
3700	Fluid Mechanics	2	1	1	0	2	0	2	0	0	0	1	2	2	0	2
3900	Professionalism and Ethics Seminar	0	0	0	0	0	2	0	0	1	2	2	0	0	0	0
4000	Engineering Design I: Conceptual Design and Prototype Testing	1	2	2	2	2	1	2	2	0	1	0	2	2	2	2
4010	Engineering Design II: Final Product Design	2	1	2	2	2	1	2	2	1	1	1	2	2	2	2
4060	Manufacturing Processes	2	0	2	2	2	1	2	0	1	1	2	2	1	0	1
5000	Engineering Law and Contracts	0	0	0	0	0	1	1	0	1	0	1	1	0	0	0
5010	Principles of Manufacturing Processes	2	0	2	0	2	0	1	1	0	1	1	2	1	0	2
5030	Reliability Engineering	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1
5040	Quality Assurance Engineering	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1
5050	Fundamentals of Micromachining Processes	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2
5055	Microsystems Design and Characterization	1	2	2	2	2	2	2	2	1	1	1	2	2	1	2

5060	Sustainable Products and Processes	1	0	2	0	1	2	2	2	2	2	2	1	1	0	1
5100	Ergonomics	1	2	2	2	1	1	2	0	1	0	1	1	0	2	1
5110	Introduction to Industrial Safety	1	0	1	1	1	2	0	0	1	1	1	1	0	1	1
5200	Classical Control Systems	2	1	2	0	2	0	0	0	0	0	0	2	2	0	1
5205	System Dynamics	2	0	1	2	2	0	1	2	0	0	1	2	2	0	2
5210	State Space Control	2	1	2	0	2	0	0	0	0	0	0	2	2	0	1
5220	Robotics	2	0	1	1	2	0	0	0	0	0	1	2	2	0	2
5230	Introduction to Robot Control	2	2	2	2	2	0	1	0	1	1	1	2	2	0	2
5240	Advanced Mechatronics	2	1	1	1	2	0	1	1	0	1	0	2	1	1	0
5250	Object-Oriented Programming for Interactive Systems	1	0	2	1	2	0	1	1	0	0	1	2	2	0	1
5300	Advanced Strengths of Materials	2	0	1	1	2	1	0	0	0	0	1	2	1	0	2
5400	Vibrations	2	0	2	0	2	0	0	0	0	0	0	2	1	0	2
5410	Intermediate Dynamics	2	1	1	0	2	1	1	0	0	1	1	2	2	0	2
5500	Engineering Elasticity	2	0	0	0	1	0	1	0	0	0	0	1	0	0	1
5510	Introduction to Finite Elements	2	1	1	0	2	1	1	0	0	0	1	2	2	0	2
5520	Mechanics of Composite Materials	2	0	1	0	2	0	0	0	0	0	1	1	1	0	2
5530	Introduction to Continuum Mechanics	2	0	0	0	2	1	0	0	1	0	1	1	1	0	1
5535	Biomechanics I	2	0	1	0	2	1	0	0	1	2	2	2	2	0	2
5540	Biomechanics II	2	1	1	0	2	1	1	0	1	2	2	2	2	0	2
5600	Intermediate Thermodynamics	2	0	1	0	2	0	0	0	1	1	0	2	2	0	2
5620	Fundamentals of Microscale Engineering	2	0	1	2	2	0	0	1	0	1	1	1	0	0	1
5700	Intermediate Fluid Dynamics	2	1	1	1	2	0	0	1	0	1	1	1	2	0	2
5710	Aerodynamics	2	1	1	0	2	1	0	0	0	1	0	1	2	1	1
5730	Microfluidic Chip Design and Fabrication	2	2	2	2	2	0	2	2	0	1	1	2	2	0	2
5800	Sustainable Energy Engineering	2	0	0	0	2	2	2	0	2	1	2	2	1	0	2
5810	Thermal Systems Design	2	0	2	0	2	0	2	0	1	1	1	2	2	0	2
5820	Thermal Environmental Engineering	2	0	2	1	2	1	1	1	0	0	1	2	2	0	2
5830	Aerospace Propulsion	2	0	1	0	2	0	0	0	0	0	0	2	2	0	1
5910	Cooperative Education	0	2	2	2	2	2	2	2	1	1	2	2	2	2	2
5960	Intermediate Heat Transfer	2	0	1	0	2	0	2	0	0	0	1	2	1	0	0
5960	Nanoscale Heat Transfer	2	1	1	0	2	0	1	1	1	0	2	2	2	1	1
5960	Integrated Energy Systems Analysis	2	0	1	2	2	2	2	0	2	1	2	2	2	0	2
5960	Wind Energy	2	1	1	2	2	2	2	2	2	1	2	2	2	1	1
5960	Nanotribology and Contact Mechanics	2	0	2	0	2	1	1	1	1	2	2	2	2	0	1

5960	Fundamentals of Electromech. Transducers	2	0	2	0	2	0	1	0	0	1	0	2	1	0	2
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* This is a new outcome that will become part of the continuous-improvement cycle beginning Fall 2015.

The breakdown in Table 3B-2 is summarized graphically in Figure 3B-2, below, which shows the number of core Mechanical Engineering credit hours having high (solid black bar) or some (hatched bar) activity related to each Student Outcome. All required Mechanical Engineering courses are included in this analysis, for a total of 54.5 credit hours (which are broken down by ABET curricular categories in Table 5A-1). Many of the Student Outcomes (1, 3, 5, 12, 13, 15) are addressed by most (more than 80%) of the required ME courses. All but Outcomes 8, 9, and 14 are addressed by more than 60% of the required ME courses. Outcome 6, “an understanding of the professional and ethical responsibilities of an engineer” has high activity in ME EN 3900 Professionalism and Ethics Seminar, with some activity in more than half of the other ME courses. Outcome 9, “the broad education to understand the impact of mechanical engineering solutions in a global and societal context, does not receive high activity in any of the required ME courses, but does receive some attention in more than one third of the required classes. In addition, this Outcome is addressed by the University’s General Education and Bachelor’s degree requirements (described in more detail in Criterion 5: Curriculum). Outcome 14, “participation in a capstone design project and optional participation in faculty-led research, cooperative internships, industrial design projects, and independent study projects,” is fulfilled only by ME EN 4000/4010 Engineering Design I/II when considering the required courses. Independent study/research/design and co-op experiences are taken as technical electives. While outcome 8, “the ability to effectively communicate technical information in oral presentations,” is addressed by less than 25% of required ME courses, significant attention is given to it in these courses, particularly in ME EN 1000 Introduction to Mechanical Design for Engineering Systems and ME EN 4000/4010 Engineering Design I/II.

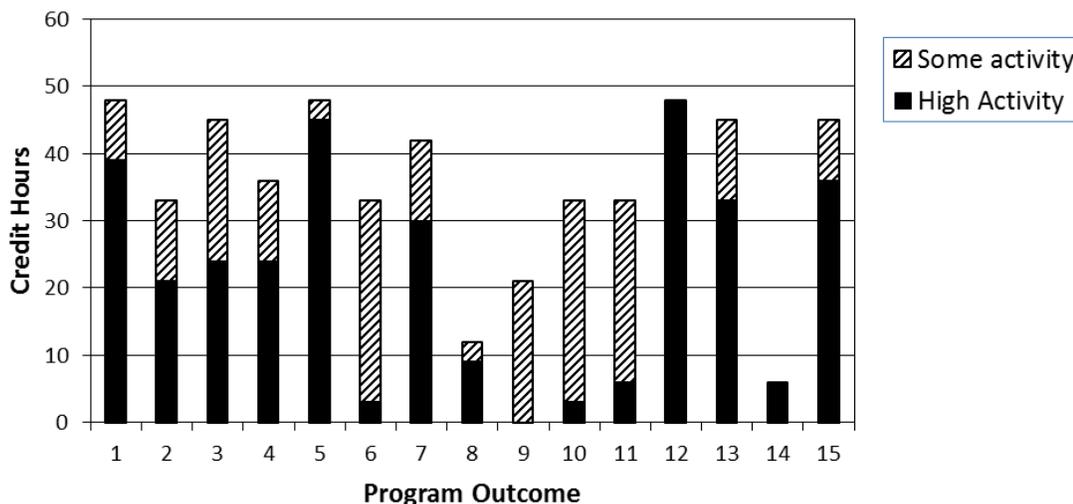


Figure 3B-2: Distribution of credit hours spent on each program outcome (based on Table 3B-2)

CRITERION 4. CONTINUOUS IMPROVEMENT

This section explains the program's processes for regularly assessing and evaluating the extent to which the student outcomes are being attained. This section also describes the extent to which the student outcomes are being attained, and how these assessment processes foster continuous improvement of the program.

As will become evident upon reading this section, all outcomes have been continually monitored, throughout this review cycle especially focusing on:

- **SPIRAL:** This was a significant NSF-sponsored revision of the freshman and sophomore curriculum to explore effectiveness and sustainability of contemporary teaching paradigms, primarily aiming to engage students through active learning and to then reinforce key learning outcomes by repeating them regularly as each student progresses through the program. Section B describes several revisions to the original SPIRAL vision based on direct and indirect assessments of its effectiveness and sustainability.
- **CREATION OF EMPHASIS AREAS:** A total of 12 optional emphasis areas were established to allow students to indicate a specialization focus on their transcripts and to indirectly serve an advising role to help students select appropriate technical electives.
- **MANUFACTURING:** These were updates/revisions to the curriculum resulting from data suggesting manufacturing is best introduced in the sophomore year.
- **MATHEMATICS:** With an aim to improve retention and competency, the College of Engineering introduced significant revisions to the mathematics sequence available to engineering students.

A. Student Outcomes (assessment processes and procedures)

This section provides the following information:

1. A listing and description of the assessment processes used to gather the data upon which the evaluation of each student outcome is based. Examples of data collection processes include, but are not limited to, collected student work, senior project presentations, nationally-normed exams, oral exams associated with the capstone "Design Day" experience, oral Ph.D. qualifier exams given to students who had gone through our undergrad program, senior exit breakfast focus groups, junior seminar, observations from industry (e.g., Boeing) on quality of capstone design projects, co-op evaluations from supervisors, and course evaluations.
2. The frequency with which these assessment processes are carried out
3. The expected level of attainment for each of the student outcomes
4. Summaries of the results of the evaluation process and an analysis illustrating the extent to which each of the student outcomes is being attained
5. How the results are documented and maintained

Below, we cover items 1 and 2 simultaneously by describing specific information resources together with their role in assessment and evaluation, where we adhere to the following definitions articulated by ABET: "Assessment is defined as one or more processes that identify, collect, and prepare the data necessary for evaluation. Evaluation is defined as one or more

processes for interpreting the data acquired through the assessment processes in order to determine how well the student outcomes are being attained.” With differences only in frequency of application, each information resource is used in a continuous-improvement cycle having components illustrated in Figure 4A-1.

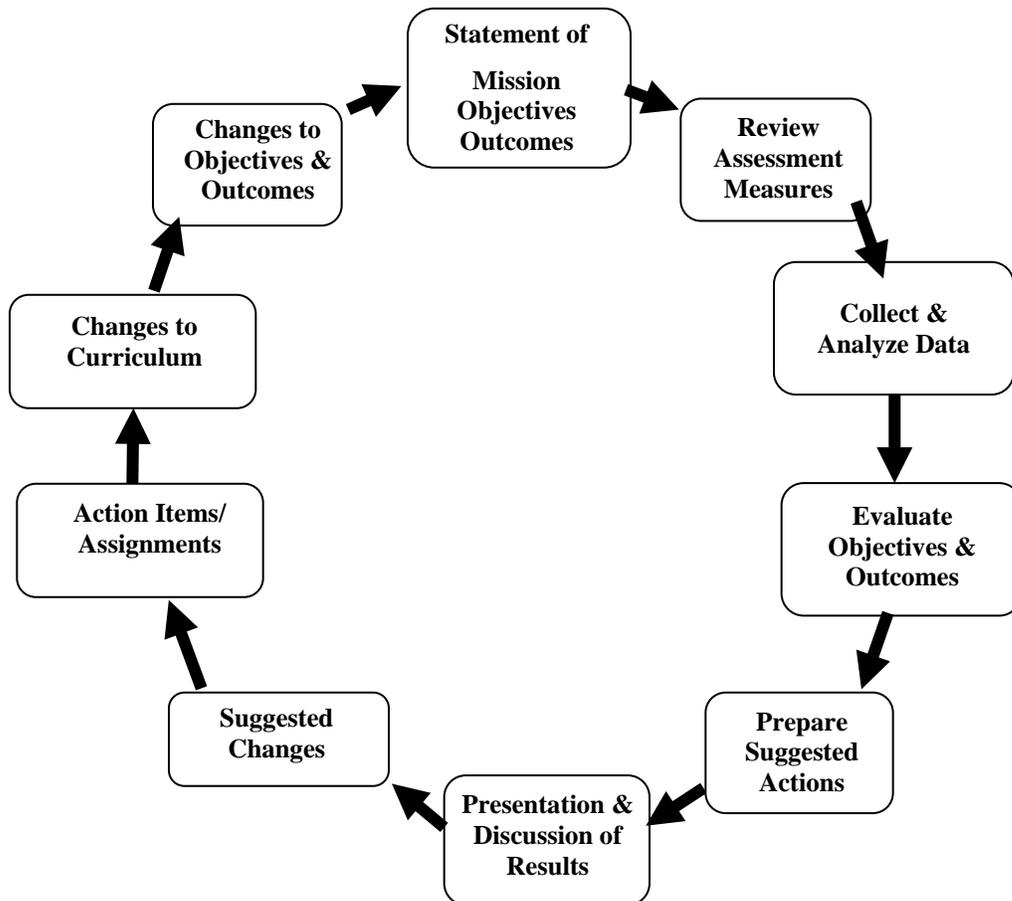


Figure 4A-1: Assessment and evaluation process used in the Mechanical Engineering Program

Information Used for Assessment and Program Improvement

This section serves as a catalog of the following information (direct and indirect) that is scrutinized to assess outcome achievement and to identify triggers for program revisions:

- Nationally-normed exams
- Collected student work and instructional material (ABET course notebooks)
- Feedback/input from college/industry partners/collaborators/advisors
- Input from Curriculum Committee discussions/deliberations

- Faculty-initiated proposals motivated by direct observations
- Nationally-normed surveys
- Written examinations
- Oral examinations
- Student surveys, interviews, and focus groups
- Student records
- Information from Alumni

These data sources are also used to subsequently check if program revisions have the intended effects.

Nationally-normed exams

Fundamentals of Engineering (FE) exam

The University of Utah is one of two Mechanical Engineering programs in the nation that requires its students to *pass* (not just take) the FE exam. Accordingly,

The University of Utah is one of two Mechanical Engineering programs with a 100% FE exam pass rate for its graduates.

Upcoming graphs show pass rates of our students on their first attempt, which are similar to national averages, but all graduates of the program ultimately pass this exam.

Collected student work and instructional material (ABET course notebooks)

Small teams of two or three faculty members per course are assigned to review samples of student work collected from all undergraduate courses (required and elective) to directly assess the degree to which outcomes associated with each course are achieved.

Opportunities for improvement are typically quite evident from these collected works. These notebooks are used to collect individual course syllabi, homework assigned, exams, special projects or problems assigned, and examples of student work.

Feedback/input from college and industrial partners/collaborators/advisors

Industry practitioners who directly interact with students

Through field trips, co-ops, summer internships, and campus visits, members of industry often interact with students to directly assess the quality of their work. Boeing Corporation, for example, gives prizes for the top three design projects on Design Day, and they debrief the faculty on their observations of student performance. In the wake of design faculty personnel changes, some previously used formalized industry assessments are no longer maintained, pending development of new rubric-based quantitative assessment data. During this transition, industry's direct observations have continued to be quite influential in program improvement.

Formal industrial advisory groups

Input on program improvement is also provided by the following groups:

- College of Engineering Industrial Advisory Board
- Engineering National Advisory Council (ENAC)

A seven-member subcommittee (specifically assigned to Mechanical Engineering) provides feedback about the degree to which a student's achievement of outcomes is important to engineering practice (which is pertinent to relevancy of objectives) and the degree to which the program's graduates appear to have sufficient education to apply what is taught in the program (through attainment of outcomes) without excessive need for remedial on-the-job training.

Co-op evaluations from supervisors

Input from co-op supervisors is solicited at the culmination of each student's ME EN 5910 Cooperative Education experience. The supervisors are asked essentially the same questions as appear in the alumni survey. They rate importance to the company as well as the student's performance in a given area.

Input from Curriculum Committee discussions/deliberations

Some outcome assessments and/or corresponding curriculum improvements come directly from discussions initiated at department Curriculum Committee meetings. This committee, consisting of nine ME faculty members and two representatives from the Undergraduate Student Advisory Committee (USAC), meets weekly during the academic year to address curriculum matters. Non-committee members often attend these meetings to deliver information and/or to convey opinions that are relevant to assessment of outcomes. The curriculum committee brings potential outcome-specific concerns to faculty meetings to broaden available data through faculty comments and suggestions related to the curriculum.

Faculty-initiated proposals motivated by direct observations

As is the case in any healthy academic environment, the program has a strong network of faculty who collaborate on curriculum development (e.g., creating a sustainable delivery of common course materials on the Campus-provided course management system, called *Canvas*). The associated course content and pace are strongly based on direct observations of student performance.

Occasionally an individual faculty member or small faculty groups will provide a proposal related to curriculum improvement. Such proposals are often the result of personal experiences, independent direct assessments, course surveys, or feedback obtained from students. Such proposals are presented first at the ME curriculum committee before being brought to the entire faculty.

Nationally-normed surveys

Educational Benchmarking Inc. (EBI) survey of graduating seniors

The EBI Survey is completed by seniors at the end of their final semester prior to graduation. This computerized survey by Educational Benchmarking Inc. provides comparisons with other educational institutions on all required ABET outcomes. The

number of responses to this survey (about 30) is slightly lower than for the Department Exit Survey. Most of the questions in this survey use a Likert scale in which answers range as follows:

- | | | |
|--------------|--------------|----------------|
| 1. Very poor | 4. Good | 7. Exceptional |
| 2. Poor | 5. Very good | |
| 3. Fair | 6. Excellent | |

The EBI survey provides comparisons against a “Select Six” group of institutions (chosen by the College):

- | | |
|------------------------------|--------------------------------------|
| 1. Oregon State University | 4. University of Notre Dame |
| 2. University of Connecticut | 5. University of Southern California |
| 3. University of Kansas | 6. University of Wisconsin – Madison |

The EBI survey also provides comparisons against institutions in the same “Carnegie class.” Our Carnegie class consists of 26 high-research-activity universities, both private and public (including our Select Six).

Many of the upcoming graphs of EBI data show a dip in scores in 2013. Only 16 students took the EBI Survey in 2013, compared to an average of 86 respondents in each of the previous five years. This corresponds to low enrollment in ME EN 4050 Concurrent Engineering II, where the EBI Survey was historically administered. Spring 2013 was the last offering of ME EN 4050, which was eliminated as part of the SPIRAL Curriculum changes. Most students in the pre-SPIRAL curriculum completed ME EN 4050 in Spring 2012, resulting in a small, non-representative group enrolled in Spring 2013.

Another aspect of the upcoming EBI graphs is that the data tend to be higher in 2014 and 2015. This corresponds to a change in phrasing of the questions. In each EBI discussion, we provide the original phrasing in the main text and the new phrasing in the caption of the figure.

Written examinations

Samples of senior design project reports are archived in the ME EN 4010 folder of the ABET course materials. These written design reports may be used to provide specific information on the content of the design projects. Traditional written exams in *all* courses (with the exception of Senior Design) are, of course, the primary mechanism for direct assessment of student learning.

Oral examinations

In-class senior project presentations

All seniors must give oral presentations (together with their team), providing an opportunity for direct assessment of oral communication.

Capstone “Design Day” student public defense

Seniors must interact with the general public to describe their design project, and some of the people they speak with then give feedback to the instructor about the skill with which they explained their work.

Qualifying exam results for Ph.D. students who had gone through our undergraduate program

A fraction of our graduating seniors go on to pursue a Ph.D. within the department. Even though this small group is not representative of the typical Mechanical Engineering undergraduate, we have come to realize that their knowledge of undergraduate topics still serves as an informative direct-assessment suitable for ranking the quality of education in each outcome area.

Student surveys, interviews, and focus groups

Traditional end-of-course surveys

In the previous review cycle, students rated every course for its contributions to every ABET outcome, but it was soon recognized that this approach adulterates results by getting low ratings for outcomes in any course that (according to Table 3B-2) is not supposed to cover it in the first place! Moreover, having such a large number of questions in student surveys probably lessened the chances of getting carefully thought-out responses. Therefore, beginning in this review cycle, end-of-course surveys ask about an outcome only if the outcome is identified in Table 3B-2 as having a “high level” of activity.

Figure 4A-2 shows a sample graph from course surveys over a span of four years with error bars indicating \pm one standard deviation (2015 data were not yet available at the time of this Self Study). The graph in Figure 4A-2 is atypical because it has gaps (meaning simply that none of the summer courses mark Outcome 9 as having significant coverage). This graph is also atypical because it has quite a bit of variation from year to year. In fact, this is the only student survey showing a time (Fall 2012) when the score fell below the “action trigger” value of 5.5 (half way between “agree” and “mildly agree”). The large jump in the score in the subsequent semester (Spring 2012) suggests that course feedback surveys are effective alerts triggering corrective action. The full set of course survey graphs may be found at the end of the outcome-by-outcome assessments.

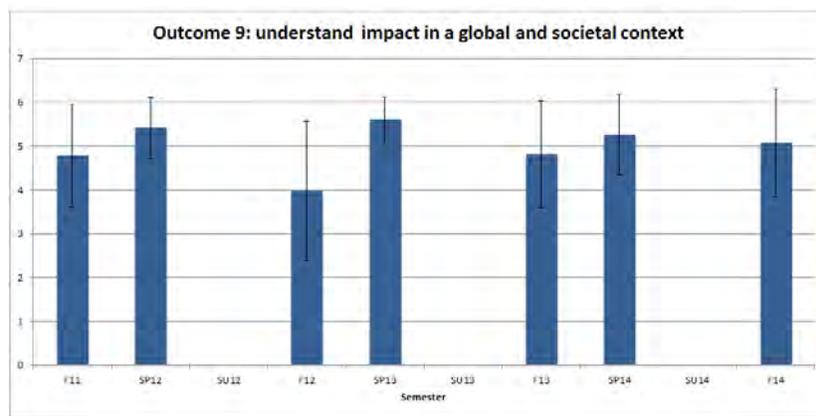


Figure 4A-2: An example of a course survey graph

Exit interview breakfast/discussion/questionnaire

Every graduating student is invited to take part in a departmental exit interview. This interview consists of two parts, written questions, composed of an online departmental survey, and an open discussion of the program. In general, questions on the departmental survey are intended to supplement those asked on the EBI survey for both outcome assessment and objective evaluation. The scale used is 1 (not important) through 4 (very important). The number of responses received to this survey has ranged from 55 to 72 in this review cycle (~50% response rate).

ME EN 3900 Professionalism and Ethics Seminar

In the ME EN 3900 seminar course, the students are given an overview of the program's assessment and improvement processes, and the seminar ends with an extended open discussion of opportunities for improvement.

Design Day interview/survey of students

Design Day is an annual (soon to become semi-annual) event in which students in ME EN 4010 Engineering Design II present posters and their realized designs in a tradeshow-like public venue. One component of this event is a required interview conducted by the course instructor in which the students are asked to present their work. Students are specifically asked to present and answer the following:

- What are the critical metrics and goals for your design?
- Evidence that design metrics have been met
- In cases where design metrics have not been met, explanations and potential recovery plans to meet metrics
- Data and analyses indicating the engineering work that went into the design

The students are evaluated not only on the intellectual merits of their work, but also on their ability to present and communicate in a clear, concise, and professional way.

Input from student advisory committees

The Department of Mechanical Engineering has two student advisory committees that provide input on program improvement:

- Undergraduate Student Advisory Committee (USAC)
- Graduate Student Advisory Committee (GSAC)

Ad hoc student committees are formed as needed to investigate outcome assessment issues as they might arise. For input on the undergraduate program, including periodic program assessment feedback, the USAC is the primary source of input. The USAC provides two members who serve as representatives on the departmental Curriculum Committee. Since 5000-level technical elective courses for undergraduates commonly meet with 6000-level introductory graduate courses, however, the GSAC does have some involvement in providing input into technical elective courses. Moreover, the GSAC conveys anecdotal feedback on the adequacy of the undergraduate program in preparing students for graduate school. In their roles as course TAs, the graduate students provide detailed direct assessments of student achievement, which allow for "real time" adjustments in how the courses are taught in order to immediately rectify threats to outcome achievement.

Student records

The DARS system and the Department's *ManageME* database are used to track which elective courses are selected by students in the program, and it is an essential resource to research issues in individual student performance. This system might also be used to assess outcomes that have a metric based on frequency of student enrollment (e.g., co-op, independent study, etc.)

Information from Alumni

The Alumni survey is sent to Mechanical Engineering graduates who received their B.S. degree three to five years ago. These surveys are useful in assessing objectives, but are used only to a limited degree for outcome assessment because of the time lag between their curriculum and the current curriculum. As explained below, however, this time lag can allow the alumni survey to act as an assessment of our assessment process itself. For example, by the time we hear from Alumni that a certain curricular component needs attention, our other assessment practices should have already identified the need for corrective action. Otherwise, if the Alumni report an issue that was not already identified in our other assessments, we must examine how to repair the gap in our improvement process.

Our departmental alumni survey ensures that respondents make a distinction between objectives and outcomes. Aside from separately asking about objectives, the survey also has them separately rank *importance* of the outcomes in their careers (which serves as this constituencies input to whether or not objectives are consistent with outcomes) and the *degree to which the program* prepared them by the time of graduation. Prior to 2011, the survey had asked alumni to rate *their ability* in various outcome-related areas, but the wording was changed to ask *how well the program prepared them*, as this phrasing better ascertains the ability to apply *their education* without having to relearn the material through on-the-job training.

Information synthesis by the ABET committee

Using data from the above-listed sources, the assessment and evaluation processes are coordinated by the Mechanical Engineering ABET Committee, composed of the department Chair, three faculty members, and two staff members for administrative support. Direct assessments, usually conducted by individual course instructors but also including nationally-normed exams, are integral to the process. Additionally, twice per review cycle (specifically, September 2012 and May 2015 for this cycle), status on all aspects of continuous improvement is assembled in a report that is delivered and presented to the College of Engineering ABET Committee. The Mechanical Engineering report in 2012, for example, used ABET's own program-evaluator forms in a mock interim self-assessment to identify strengths and shortcomings of our assessment process.

The overall assessment and evaluation process developed by the Department of Mechanical Engineering is illustrated in Figure 4A-1, and its timeline is summarized in Table 4A-1. This process begins with a review and update of the departmental Mission Statement, the Program Educational Objectives, and Student Outcomes. Next, the assessment measures are reviewed and updates are made based on previous assessments and experience. The process next moves into the data collection phase, where the various assessment tools are implemented. The assessment tools used for the Student Outcomes are listed and described later in this section. As data becomes available, it is reduced and tabulated/plotted by members of the departmental staff as well as the ME Curriculum Committee. Results are reviewed by the Curriculum Committee

first, and then the results are disseminated to the faculty, and to the program’s industrial advisors. Generally, an oral presentation is made by the chair of the Curriculum Committee to the ME faculty, either at regularly scheduled faculty meetings or at the annual summer faculty retreat. This information is also presented to representatives from industry (e.g., ENAC). Based on the ensuing discussions, action items are generated and assigned to address specific aspects of the program. Actions may include changes to the curriculum, to assessment measures and practices, and possibly to the stated outcomes, objectives, and mission statement. Such actions are usually assigned to either specific faculty members or staff, to departmental groups, or to the ME Curriculum Committee. The Curriculum Committee monitors the progress of these action items.

Table 4A-1: Assessment and Evaluation Tasks and Timeline

Assessment Process Task	Responsible Group(s)
Review/update mission statement, objectives, and outcomes (annually)	ABET Committee
Review/update assessment measures/tools (annually or more often as needed)	Curriculum and ABET Committees
Collect data (solicited from various groups) Exit interviews (once per year) Exit survey (once per year) Alumni survey (every other year) FE Exam (at least twice per year) EBI Survey (once per year) Student Course Feedback Survey ABET Notebooks independent direct assessment of coursework and examinations (twice per cycle or as needed) Student Records (as needed if issues are identified) Capstone Design Projects (twice per year) Communication Staff Report (annually in the first half of this cycle)	ABET Committee Department Staff Department Staff Department Staff Department Staff College Staff Center for Teaching and Learning Excellence (http://ctle.utah.edu/scf/) Department Faculty Department Staff Department Faculty Communications Staff
Analyze/summarize data: Evaluate achievement of objectives and outcomes (all assessments analyzed at least twice per ABET cycle, with a major mid-cycle review coordinated by the College)	ABET Committee

(Continually, as needed) suggest changes to: Assessment measures Assessment process Curriculum Outcomes Objectives Mission Statements	Curriculum and ABET Committees
Produce report for faculty & industrial advisors (twice per review cycle)	Curriculum and ABET Committees
Present/discuss report at department retreat and other venues (annually)	ABET and Curriculum Committees Faculty ENAC USAC
Add “plan of action” to report	Curriculum and ABET Committees
Assignment and monitoring of action items	Curriculum Committee Faculty
Enact changes to: Curriculum Assessment measures Assessment process	Curriculum Committee Faculty
Review/update mission statement, objectives, and outcomes (at least annually)	Strategic Planning Committee Curriculum Committee Faculty

Evidence Provided to Support the Level of Achievement

A summary of the assessment information used to evaluate the level of achievement of each Student Outcome is provided in the following section. Additionally, ABET course notebooks from all Mechanical Engineering courses will be available for the evaluation team. These notebooks, which contain the syllabus, homework assignments, quizzes, exams, and examples of student work, provide direct assessments of achievement of specific outcomes. Senior design reports and posters, which are on display for visitors, also supplement regular coursework and exams. These traditional, yet still effective, forms of direct evidence allow instructors to immediately rectify shortcomings by adjusting the course emphasis or teaching methods. Survey forms, survey results, and other assessment data are also available for examination as part of the program materials.

Multiple outcome “snapshot” assessments

This section presents assessment results for multiple outcomes compared with each other in the form of a “snapshot” of data at a given moment in time (whenever the assessment was most recently made). In such ensemble snapshot analyses, the trigger for program improvement is simply that an outcome belongs to the lowest scoring group relative to other outcomes.

Alumni Survey and Co-op Employer Evaluation snapshot results

Recall that Figures 3B-1a and 3B-1b sorted outcome-related topics based on what the Alumni and co-op supervisors respectively deemed to be least-to-most important to on-the-job performance. Such plots served to confirm alignment of the curriculum with program objectives. For the purpose of continuous improvement, Figures 4A-3a and 4A-3b revise these plots to sort the outcome-related topics based on the *discrepancy* between the outcome’s importance and the program’s success at achieving it.

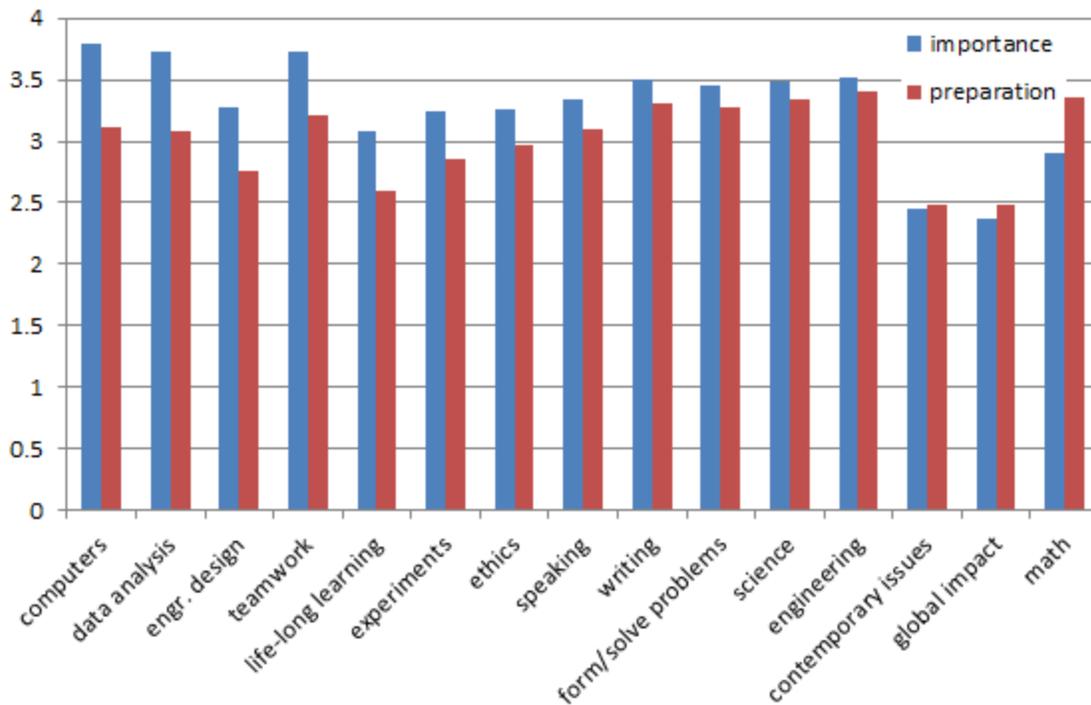


Figure 4A-3a: Outcome-related skills, ranked by the *discrepancy* between importance of the skill in engineering practice and the preparation in the skill from the program

(Data from 2014 alumni survey)

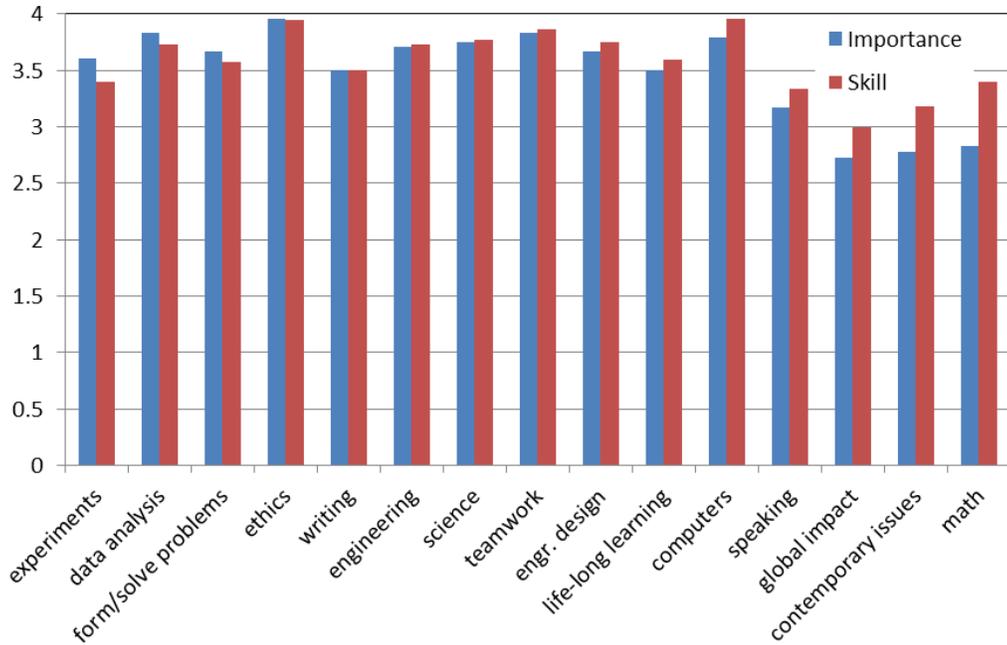


Figure 4A-3b: Outcome-related skills, ranked by the *discrepancy* between importance of the skill in engineering practice and the preparation in the skill from the program

(Data from Summer 2014 through Spring 2015 co-op supervisor survey)

The preparation scores reported by the alumni refer to the older (pre-SPIRAL) curriculum, since the survey is administered three to five years after graduation. The lowest (far-left) four categories in Figure 4A-3a (computers, data-analysis, design, and teamwork) therefore indicate areas that needed the greatest attention in *this* review cycle. Those same curricular areas were indeed among the primary focus of the SPIRAL curriculum revisions reported in this Self Study. Given that alumni feedback about “degree of preparation” is time delayed, we conclude that alumni data serves to confirm that our *other* (faster turn-around) data sources are indeed adequate to identify the most urgent focus areas for program improvement.

As seen in the far-right columns of Figure 4A-3a, our Alumni report that they were “over-educated” in mathematics in comparison to its importance in their careers, and this view was shared by the co-op supervisors (Figure 4A-3b). This result has triggered a plan to more carefully scrutinize the Alumni data to see if there is a difference when separately considering graduates who went to industry jobs compared to those who went to academic or research positions. Interestingly, the figures show that “the ability to analyze data” is very important, yet not well covered. This observation supports the program revisions already in the planning stage to add a required statistics course to the curriculum.

Review of ME EN 3900 course material

ME EN 3900 Professionalism and Ethics Seminar is a 0.5 credit required seminar course that is taken by juniors during their Fall semester. The seminar course meets weekly and features an invited speaker for each meeting. Attendance is required, and students must sign in to receive credit for attending.

An assessment of the individual seminars from Fall 2014 was performed by the faculty member in charge (Debra Mascaro). Each seminar was given a numerical rating corresponding to the level at which a specific outcome was addressed in the seminar:

- 0 = not addressed
- 1 = addressed to a low degree
- 2 = addressed to a high degree

Figure 4A-4 shows the number of seminars (out of 14 total) that cover Outcomes 6, 9, 10, and 11 to a high or moderate degree.

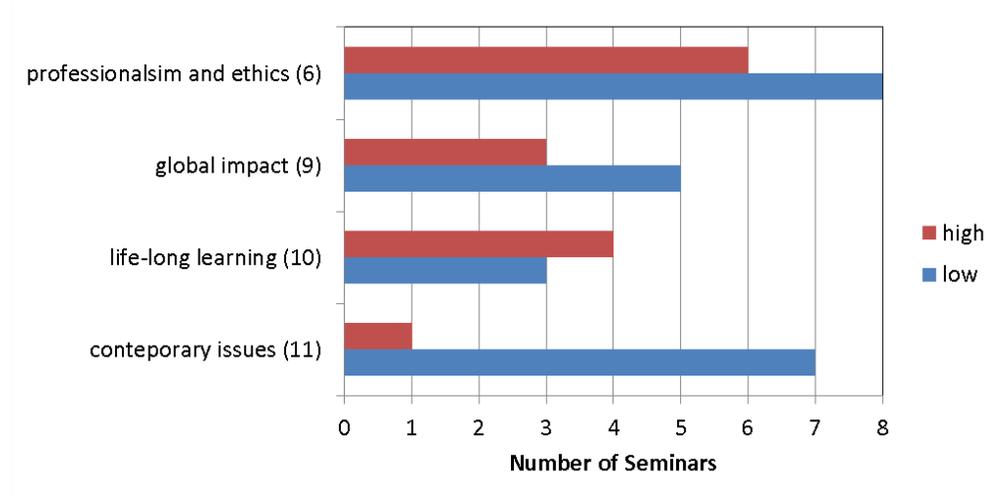


Figure 4A-4: Outcome coverage review for Fall 2014 ME EN 3900 seminars

Qualifier Exam pass rate for students who earned their B.S. in this program (2015)

Table 4A-2 summarizes the subject pass rate for University of Utah B.S. graduates on the Mechanical Engineering Ph.D. qualifying exam during the period 2009 – 2015. While these students constitute a small non-typical subset of the program’s graduates, their performance nevertheless suggests that Design and Linear Algebra need attention in the curriculum (see, for example, ACTION 1 and ACTION 20 in Section B).

Table 4A-2: subject pass rate for B.S. alumni in Mechanical Engineering qualifier

Subject	Total	Passed 1st Attempt	1st Attmpt Pass Rate	Passed 2nd Attempt	2nd Attmpt Pass Rate	Overall Pass Rate
<i>Biomechanics</i>	3	2	67%	1	33%	100%
<i>Calc. and Diff. Equations</i>	1	1	100%	0	0%	100%
<i>Composite Materials</i>	4	4	100%	0	0%	100%
<i>Controls</i>	6	5	83%	1	17%	100%
<i>Design</i>	4	3	75%	0	0%	75%
<i>Dyanamics</i>	2	2	100%	0	0%	100%
<i>Ergonomics</i>	3	3	100%	0	0%	100%
<i>Finite Element Methods</i>	1	1	100%	0	0%	100%
<i>Fluid Mechanics</i>	6	6	100%	0	0%	100%
<i>Functional Anatomy</i>	1	1	100%	0	0%	100%
<i>Heat Transfer</i>	4	4	100%	0	0%	100%
<i>Linear Algebra</i>	7	5	71%	1	14%	86%
<i>Manufacturing</i>	1	1	100%	0	0%	100%
<i>Materials Engineering</i>	3	3	100%	0	0%	100%
<i>Numerical Methods</i>	3	3	100%	0	0%	100%
<i>Robotics</i>	4	3	75%	1	25%	100%
<i>Statistics</i>	4	3	75%	1	25%	100%
<i>Strength of Materials</i>	11	9	82%	2	18%	100%
<i>Sust. Energy Engineering</i>	1	1	100%	0	0%	100%
<i>System Dynamics</i>	1	1	100%	0	0%	100%
<i>Thermodynamics</i>	4	4	100%	0	0%	100%
<i>Vibrations</i>	1	0	0%	1	100%	100%
TOTAL	75	65	87%	8	11%	97%

Curriculum Committee outcome review

In Fall 2013, the Curriculum Committee dedicated several meetings to thoroughly reviewing student work and direct-assessments (faculty observations) of student performance in each outcome. Their summary in Figure 4A-5 was presented at the 2014 Faculty summer retreat in order to ask questions that were not clearly answered in the data for outcomes 10 and 11, as well as to stimulate appropriate continuous improvement actions on outcomes 2, 5, 6, 7, 8, and 9.

- Prior to graduation, each student in the University of Utah Mechanical Engineering Bachelor of Science Program will demonstrate:
- ABET
- (a) 1. A background and depth in mathematical, scientific and engineering principles sufficient to apply this knowledge to mechanical engineering problems.
 - (b) 2. The ability to **design** and conduct experiments and subsequently analyze the resulting data for design or other engineering purposes. (concern with experiment design)
 - (c) 3. The ability to design a mechanical engineering system, component, or process for achieving a desired goal.
 - (d) 4. The ability to use teamwork in pursuit of a multidisciplinary goal.
 - (e) 5. An ability to **identify, formulate** and solve mechanical engineering problems. (concern with identifying, formulating)
 - (f) 6. An understanding of the professional and **ethical** responsibilities of a mechanical engineer. (unclear where ethics are taught)
 - (g) 7. The ability to effectively communicate technical information in written reports and memos. (concern whether students receive quality feedback)
 - (g) 8. The ability to effectively communicate technical information in oral presentations. (future uncertain with CLEAR)
 - (h) 9. The broad education to understand the impact of mechanical engineering solutions in a global and societal context. (do Gen Ed courses satisfy?)
 - (i) 10. An understanding of the need for, and the ability to remain current in engineering practices through lifelong learning. (does Seminar satisfy?)
 - (j) 11. A knowledge of contemporary issues impacting engineering. (does Seminar satisfy?)
 - (k) 12. Competency in the application of techniques and skills necessary for mechanical engineering practice.
 - (k) 13. Competency in the application of modern computer-based tools for solving engineering problems.
 - 14. Participation in a capstone design project and optional participation in faculty-led research, cooperative internships, industrial design projects, and independent study projects.

Figure 4A-5: Outcomes identified by the Curriculum Committee as potential concerns

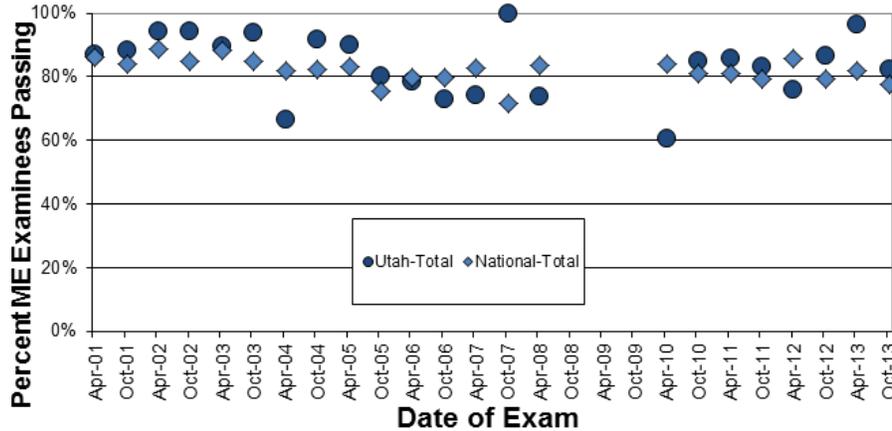
For some of the outcomes marked in Figure 4A-5, there was merely a question posed by the committee, thus triggering improvements in management of assessment data so that future committee meetings would not need to take their questions to the Faculty Retreat to get them answered. The term “concern” in Figure 4A-5 was selected to be consistent with terminology in ABET’s Accreditation Policies and Procedure Manual (APPM). In other words, the committee concluded all outcomes were being met, but that some continuous improvement actions (detailed in Section B) should be triggered in order to achieve these outcomes in the future.

Multiple outcome (holistic) assessment histories

Unlike the previous section, which summarized achievement of outcomes relative to each other in a fixed “snapshot” year, this section examines outcome attainment trends over a span of years. This section, which covers assessments that encompass multiple outcomes, will be followed by individual outcome-by-outcome analysis in the subsequent section.

Fundamentals of Engineering (FE) Exam

Recall that passing the FE Exam is a graduation requirement, giving our graduates a 100% pass rate. Of course, our students might not pass on their first attempt. The generally 80-90% pass rate in the following figure merely represents a given attempt. No FE data in the plot's "gap" were available at the time of writing this Self Study. As seen in the graph, the single-attempt pass rate for University of Utah ME students continues to be slightly above the national average (with variability in data resulting from statistically small samples – i.e., fewer students taking the exam). Our students often elect to take the exam during the Spring semester of their junior year such that they can retake the exam (if necessary) during their senior year. This choice undoubtedly affects the level of preparation for the exam, possibly bringing down the overall pass rate. In other words, filtering the data to show pass rates for only seniors would likely show an even more favorable gap between Utah students and the national average. Ultimately, our students must pass the exam as a graduation requirement, thus far outflanking the national average.



**Figure 4A-6: Pass rate of students taking the Fundamentals of Engineering (FE) Exam
To graduate from the program, Utah students re-take the exam until they pass it.**

For the FE exam, the “trigger” prompting continuous-improvement action would be the occurrence of a noticeable dip in scores, which clearly has not happened recently. A dip in scores triggers investigation only if the number of students taking the exam is large enough to be statistically significant, in which case, the exam results would be examined in greater detail (by topic area) to identify the reason for the dip.

Outcome-by-outcome assessment histories

This section examines the extent to which each individual student outcome is attained over a span of years. As will be seen, the results are generally stable at quite acceptable achievement levels over time. For the EBI results in the last two years, keep in mind that the testing agency changed the wording of the questions from “rate your education in [skill]” to “rate your confidence in [skill],” which we hypothesize to be the source of the noticeable upward jump in scores for all outcomes assessed by that survey.

OUTCOME 1: MATH AND SCIENCE SUFFICIENT TO APPLY TO ENGINEERING

Prior to graduation, each student in the University of Utah Mechanical Engineering Bachelor of Science Program will demonstrate a background and depth in mathematical, scientific and engineering principles sufficient to apply this knowledge to mechanical engineering problems.

Summary of Assessment:

The program requirement that all students must pass the Fundamentals of Engineering (FE) exam is a strong indicator that this outcome is being met. Additionally, responses received from graduating seniors on the EBI survey as well as the departmental exit survey indicate that these students feel quite positive about the engineering education they received. Nevertheless, this review cycle has seen a more detailed examination of mathematics courses to address observations in several engineering courses that students would benefit from incorporation of engineering examples in their mathematics sequence, as well as to address overall engineering program pass rates. Whereas FE exam results suggest no issue regarding *ultimately* achieving a satisfactory level of performance for this outcome among all *graduates* of the program, data for completion rates suggest that difficulty with mathematics is a major reason for students to fail to complete the program and these difficulties have collateral detrimental effects on the ability of students to apply mathematics properly in their engineering courses. Interestingly, our Alumni report that they were “over-educated” in mathematics in comparison to its importance in their careers, and this view was shared by co-op supervisors. In comparison, the Alumni report being slightly underprepared in science and math relative to its importance.

Recommended Action:

Evidence (detailed below) indicates that Outcome 1 is being met by the program’s *graduates*. However, a desire to reduce dropout rates by improving learning prior to graduation has motivated the development of an engineering mathematics sequence. The key thrust of this initiative is to ensure that mathematical concepts are introduced in the context of applications in physics and engineering. Preliminary assessments of its effectiveness at reducing dropout rates (and decreasing time required for program completion) are provided near the end of the Outcome 1 details below. Additionally, in response to survey data suggesting that our students and graduates are “over-educated” in math, we plan to more carefully scrutinize the Alumni data to see if there is a difference when separately considering graduates who went to industry jobs compared to those who went to academic or research positions.

Direct Assessment of Outcome 1

Fundamentals of Engineering Examination Assessment of Outcome 1

The program’s FE exam pass rate is 100%. This exam covers mathematics, basic science, and engineering topics, so this is strong evidence of meeting this outcome by the time of graduation.

Assessment of Capstone Design Projects for Outcome 1

Evidence of students’ ability to apply mathematical, scientific and engineering principles in the Capstone Design sequence is provided under Outcome 2.

Indirect Assessment of Outcome 1

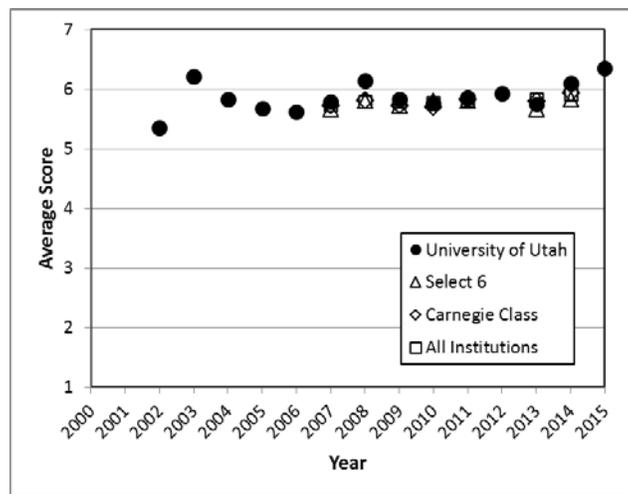
EBI Survey Assessment of Outcome 1

Three questions on the EBI survey of graduating seniors are directly related to this outcome:

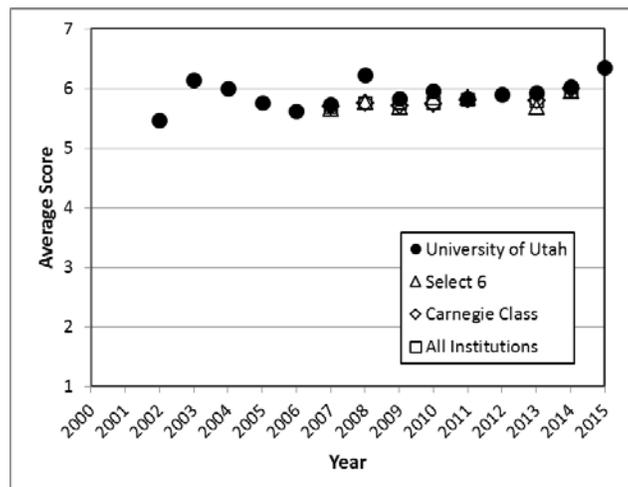
To what degree did your engineering education enhance your ability to apply your ...

- ... knowledge of mathematics?
- ... knowledge of science?
- ... knowledge of engineering?

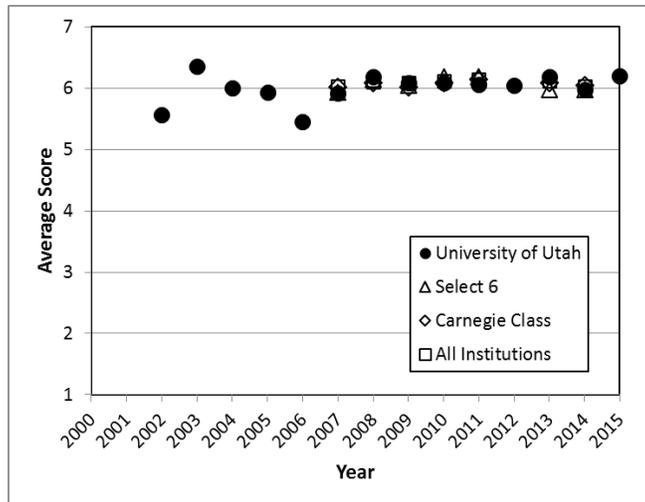
In 2014, the phrasing changed to what is shown in the figure captions below (Figures 4A1-1, 4A1-2, and 4A1-3). Scores ranged from 1 (not at all) to 7 (extremely).



**Figure 4A1-1: Response to EBI Survey Question:
“I am confident that I can apply my knowledge of mathematics”**



**Figure 4A1-2: Response to EBI Survey Question:
“I am confident that I can apply my knowledge of science”**

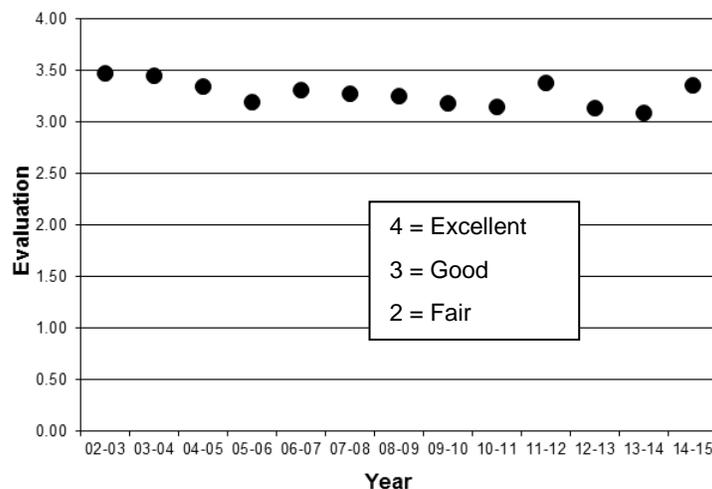


**Figure 4A1-3: Response to EBI Survey Question:
“I am confident that I can apply my knowledge of engineering”**

The average responses from University of Utah ME students for these three questions are equal to or slightly above the averages for the select six, the Carnegie Class schools, and for all EBI client schools. These data suggest that our students have acquired sufficient depth in math, science, and engineering to address mechanical engineering problems.

Departmental Exit Survey Assessment of Outcome 1

Recall that questions on the departmental exit survey are intended to supplement those asked on the EBI survey. Thus, only one question on the departmental survey relates to this outcome, “The quality of the engineering education I received.” Figure 4A1-4 shows the data on a 1 to 4 scale (poor to excellent). The responses received from this question indicate that students view the quality of the engineering education received as good to excellent, with average scores ranging from 3.2 to 3.5.



**Figure 4A1-4: Response to Exit Survey Question:
Rate “the quality of the engineering education I received”**

Engineering Mathematics Committee Assessment of Outcome 1

A new engineering math sequence was started in Fall 2012. The sequence was designed by faculty members in Mathematics and Engineering with two goals: to provide a more streamlined presentation by deemphasizing proofs and to connect the mathematics to practical applications. The traditional and engineering math sequences are outlined in Table 4A-1. The engineering track is 16 units, the traditional, 17 units. The two sequences share one course, MATH 2250 Linear Algebra and Differential Equations. Most transfer students follow the traditional track because the engineering path is not available at two- and four-year colleges in Utah. Most native engineering students pursue the engineering track. The traditional track requires five semesters, while the engineering track requires four semesters. Students following the traditional track typically take MATH 2250 Linear Algebra and Differential Equations before MATH 2210 Calculus III in order to satisfy co- and prerequisites for sophomore engineering courses.

Table 4A1-1: Outline of Traditional and Engineering Math Sequences

Traditional Track	Common Courses	Engineering Track
MATH 1210 Calc I (4)		MATH 1310 Eng Calc I (4)
MATH 1220 Calc II (4)		MATH 1320 Eng Calc II (4)
MATH 2210 Calc III (3)		
	MATH 2250 LA & DEs (4)	
MATH 3150 PDEs (4)		MATH 3140 Vector Calc and PDEs (4)
17 units		16 units

Professor Will Nesse in the Department of Mathematics has been largely responsible for staffing, monitoring, improving, and assessing the engineering math track. It was originally hoped that the engineering track would include engineering applications. These applications were to be the focus of the labs or recitation sections and were initially developed by a handful of faculty members in engineering. It soon became apparent, however, that the engineering examples required background that most students did not have. For this reason, the applications for the engineering track have been chosen primarily from physics. This approach works well because the students are generally taking PHYS 2210 and 2220 at the same time they are taking MATH 1320 and MATH 2250. The text chosen for MATH 1310 and 1320 (James Stewart, *Calculus: Concepts and Contexts*, 4 ed. (2010)) also emphasizes physics applications.

Dr. Nesse's evaluation of the engineering sequence is summarized below. His analysis ignores honors students, includes transfer students, and covers the Fall 2012 to Summer 2014 semesters. It includes engineering students from multiple departments, not just Mechanical Engineering. He tracked all of the courses listed in Table 4A1-1 and looked at pass rates, grade distributions, the

time to go from MATH 1210/[1310] [Engineering] Calculus I thru MATH 2250 Differential Equations and Linear Algebra, and the time to go from MATH 1210/1310 thru MATH 3140 Vector Calculus and Partial Differential Equations or MATH 3150 Partial Differential Equations. His results are summarized in Figures 4A1-5 to 4A2-7 and are discussed below.

In general, the pass rates for the engineering track are better than or equivalent to those for the traditional track. Figure 4A1-5 shows that in MATH 1210/1310 the pass rates (grade of C or better) are 70% and are similar for the two tracks, but in MATH 1220/[1320] [Engineering] Calculus II the pass rates in the engineering track are significantly higher: 88.1% versus 72.6%. The grade distributions in MATH 1210/1310 are nearly identical but in MATH 1220/1320 there are significantly more A's and B's in MATH 1320. This may be because the topics in MATH 1320 partially overlap with those in PHYS 2210 Physics for Scientists and Engineers I so that the students in MATH 1320 are being exposed to some topics twice.

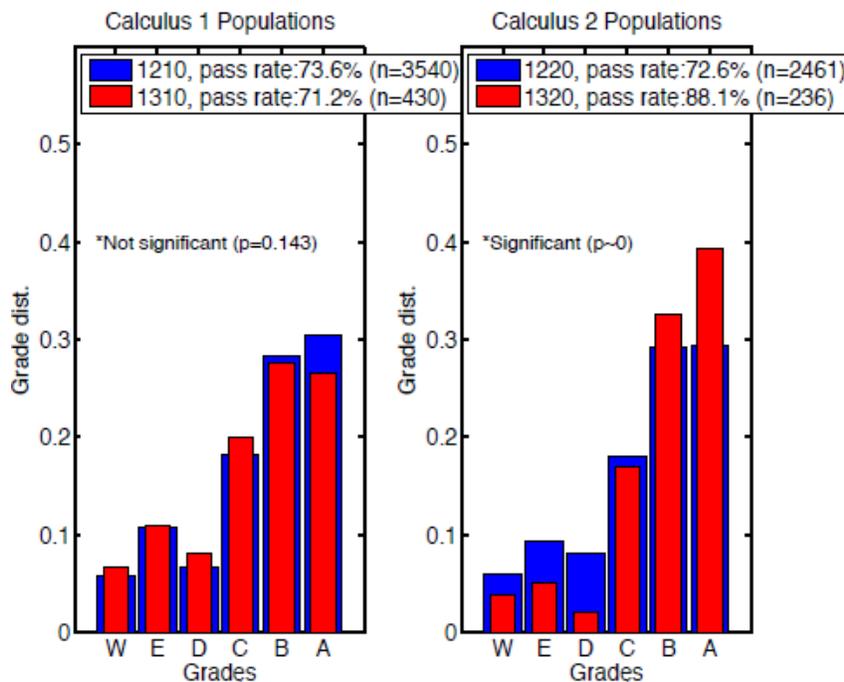


Figure 4A1-5: Pass rates and grade distributions for MATH 1210/1310 (Calc I) and 1220/1320 (Calc II)

The pass rates and grade distributions for MATH 2250 Differential Equations and Linear Algebra are given in Figure 4A1-6. This course is shared by the traditional and engineering tracks; the grade distributions are quite similar but the pass rates are 94% for students in the engineering track and 85% for those in the traditional track. The pass rates for MATH 2210 Calculus III are also given in Figure 4A1-6. This course is not part of the engineering track but is commonly taken by transfer students in engineering who do not have access to the engineering track before transferring to the University of Utah. The pass rate is 78%. The pass rates and

grade distributions for MATH 3140 Vector Calculus and Partial Differential Equations (engineering track) and MATH 3150 Partial Differential Equations (traditional track) are also given in Figure 4A1-6. The pass rates are similar but the grades are considerably higher in MATH 3140.

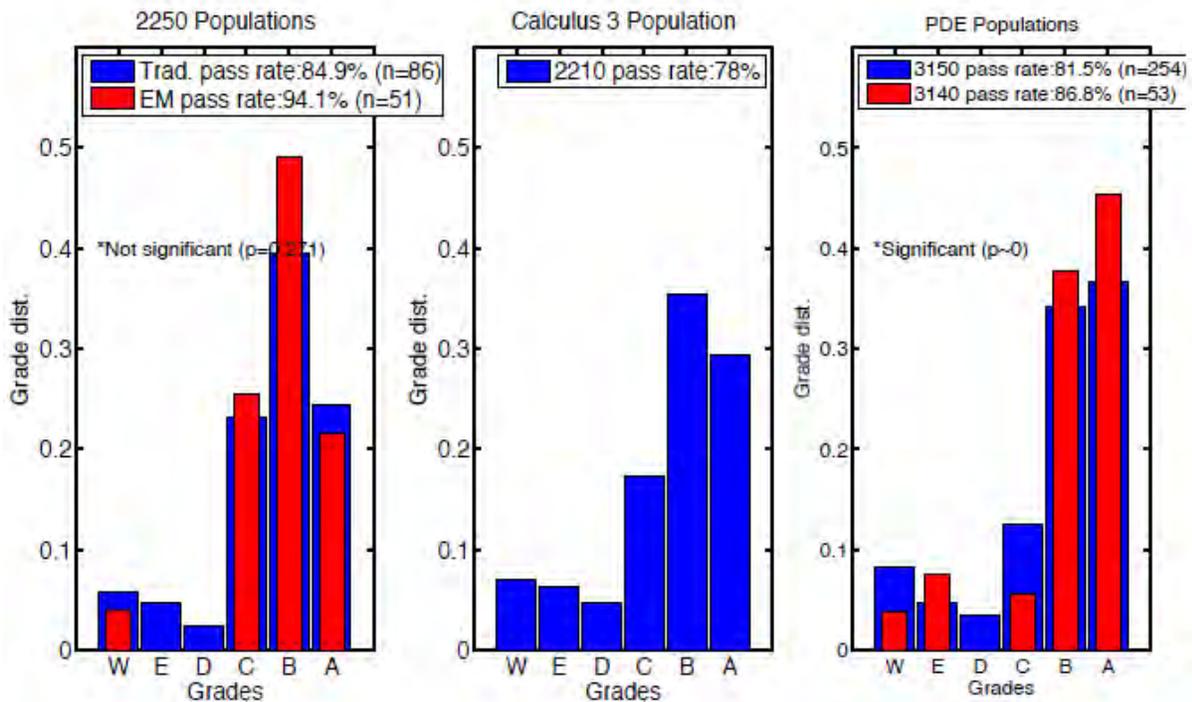


Figure 4A1-6: Pass rates and grade distributions for MATH 2250 (LA & DEs), 2210 (Calc III), and 3140/3150 (PDEs)

The number of consecutive semesters from MATH 1210/1310 through MATH 2250 is shown on the left in Figure 4A1-7. For the traditional track it takes, on average, 4.9 semesters while for the engineering track it takes 4.0 semesters. This difference is probably due to the elimination of MATH 2210 Calculus III from the engineering sequence. Preliminary data for the number of consecutive semesters from MATH 1210/1310 through MATH 3140/3150 is shown on the right in Figure 4A1-7. This graph is based on just one year of MATH 3140 students and is therefore provisional in nature. It suggests, however, that there is a large decrease in the time to finish the entire engineering math sequence relative to the traditional sequence.

The puzzling feature of Figure 4A1-7, showing that a handful of students go through the entire sequence in one or two semesters, is due to students repeating an earlier course for a better grade. In some cases it also happens when students who are returning from a leave of absence decide to take an earlier course as a refresher. These actions cause a bit of confusion in the analysis summarized in Figure 4A1-7.

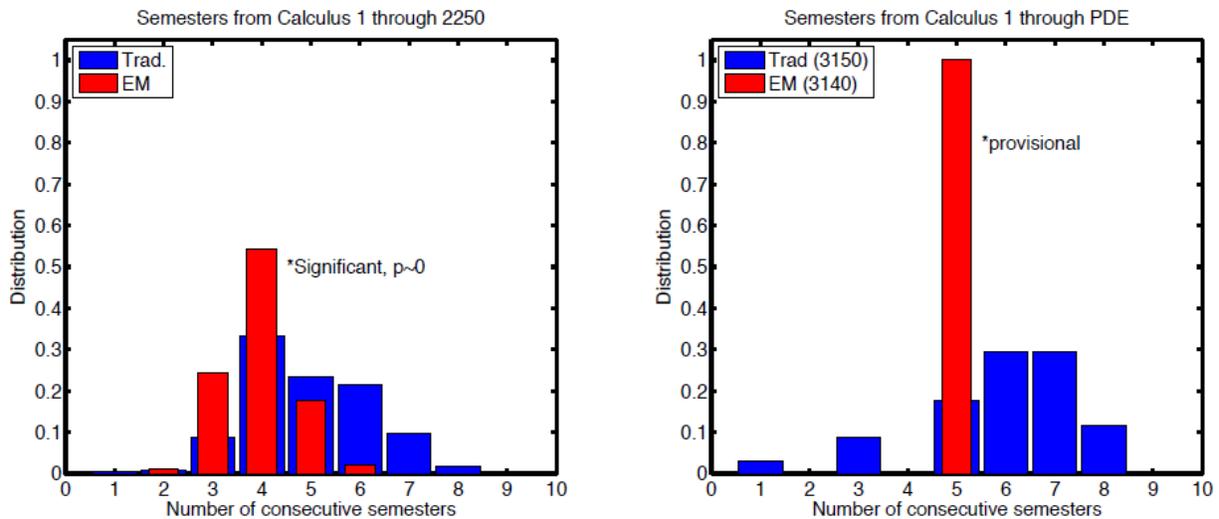


Figure 4A1-7: Number of consecutive semesters for 1210/1310 (Calc I) through 2250 (LA & DEs) and for 1210/1310 (Calc I) through 3140/3150 (PDEs)

In conclusion, the engineering and traditional math sequences have roughly similar grade distributions and pass rates, with grades and pass rates just moderately higher for the engineering track. Students in the engineering sequence, however, tend to finish their math in one less semester. This is partly due to the elimination of MATH 2210 Calculus III from the engineering sequence as shown in Table 4A-1. Although these results are not specifically for Mechanical Engineering students, they suggest that the engineering math sequence is providing an effective and efficient route to satisfying the mathematics portion of Outcome (a): an ability to apply knowledge of mathematics. The applications are primarily physics related and there is a nice overlap of mathematical topics in MATH 1320 and PHYS 2210. This overlap is so significant that the Math and Physics departments are exploring braiding the two courses via their recitation sections.

OUTCOME 2: DESIGN/CONDUCT EXPERIMENTS AND ANALYZE DATA

Prior to graduation, each student in the University of Utah Mechanical Engineering Bachelor of Science Program will demonstrate the ability to design and conduct experiments and subsequently analyze the resulting data for design or other engineering purposes.

Summary of Assessment:

The experiences received in our B.S. program provide students with sufficient opportunities to conduct experiments and analyze data. This experience is obtained primarily in the junior-level courses with laboratory components as well as in the capstone design projects. The capstone design projects also provide students with an ability to design experiments, whereas currently there is only one junior-level laboratory experience that emphasizes the design of experiments. Thus, while students are demonstrating the ability to design and conduct experiments, as well as to analyze the resulting data, more exposure to the design of experiments is warranted. In addition, Alumni responding to the 2014 departmental alumni survey indicated that “the ability to analyze data” is very important in their careers, yet not well covered in the curriculum.

Recommended Action:

Increase the number of laboratory activities in the junior-level lab courses that provide students with an opportunity to design experiments. Provide more instruction in design of experiments and statistics. (See proposed curriculum changes in ACTIONS 16 and 18 in Section B.)

Direct Assessment of Outcome 2

Assessment of Capstone Design Projects for Outcomes 1 and 2

During ME EN 4000 Engineering Design I, which is the first semester of the two-semester sequence that encompasses the Capstone Design Project, students are required to plan, build, and test a Critical Function Prototype (CFP), which is intended to evaluate a critical function of the overall design project. Each team presents their CFP to a panel of three to four faculty judges at the end of the semester.

The teams are assessed in the following three areas: 1) Prototype motivation and planning, 2) Prototype and results, and 3) Presentation of results. Within the “Prototype and results” section, the students are required to demonstrate execution of an experimental test plan and analysis of results. Prototype evaluations including design of experimental protocol and summary of data represent 50% of the total score for the CFP assignment. The average overall scores from 53 teams representing 250 students from Fall 2013, Fall 2014, and Spring 2015 are shown in Figure 4A2-1. The distribution by the three major evaluation criterion for the four Spring 2015 teams is illustrated in Figure 4A2-2, which shows that the heaviest weighting is in the grading category that includes design of experiments and analysis of data.

An overall score exceeding 85 is regarded as having achieved the outcome to a “high degree,” and a score between 75 and 85 represents achievement at an “acceptable degree.” As seen in Figure 4A2-1, 92% of the students perform at a high or acceptable level, with 70%

demonstrating this ability to a high degree. These results indicate that students are demonstrating an ability to design and conduct experiments and use the resulting data for Capstone Design purposes.

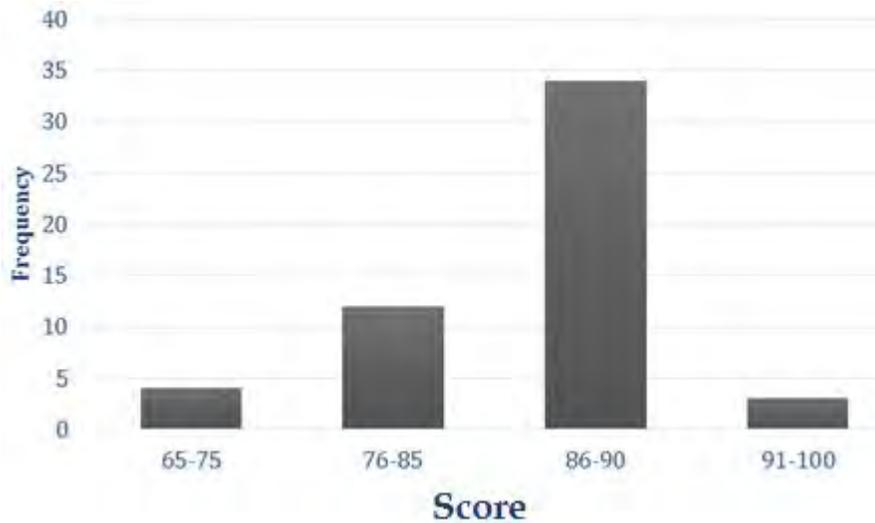


Figure 4A2-1: ME EN 4000 CFP Overall Scores

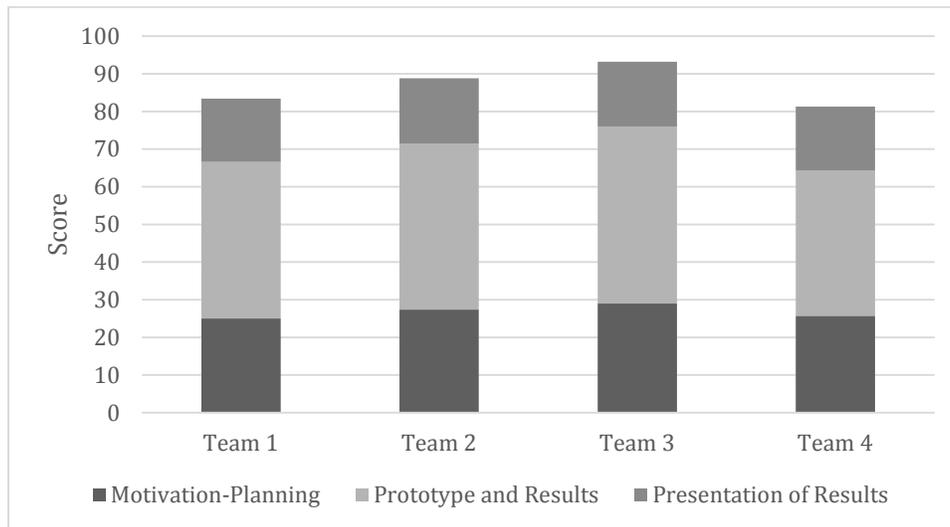
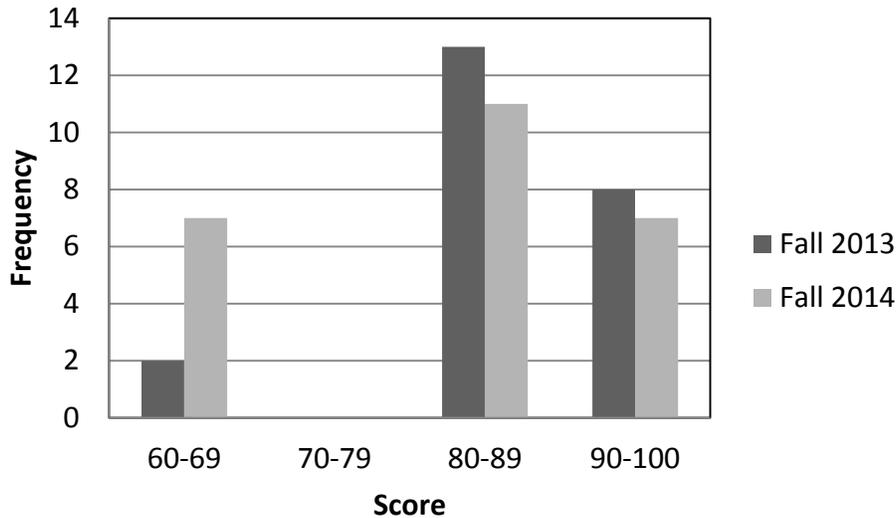


Figure 4A2-2: Spring 2015 ME EN 4000 CFP Evaluation

During ME EN 4010 Engineering Design II, the second half of the Senior Design sequence, each team is required to give three design review presentations. The faculty instructor assesses these presentations. A rubric is used for grading, which includes “Current progress – technical discussion” as one of the categories. In this category students are assessed on their ability to apply technical analysis to their specific engineering design problem. This category is worth approximately 25% of the design review grade.

Figure 4A2-3 shows the scores for this specific rubric category for two recent years (48 teams), where grades were given out on a team basis. The vast majority of the students (81%) scored above 80%, indicating a good or excellent ability to analyze and interpret data resulting from their designed experiments and engineering analyses.



**Figure 4A2-3: ME EN 4010 Design Review 3 Evaluation
“Technical Discussion”**

Review of ABET Notebooks for 3000-Level ME Lab Courses for Outcome 2

A review of the ABET Course Notebooks was performed for the 3000-level ME courses that have a laboratory component associated with the course:

- ME EN 3200 Mechatronics I
- ME EN 3210 Mechatronics II
- ME EN 3300 Strength of Materials
- ME EN 3600 Thermodynamics II
- ME EN 3650 Heat Transfer
- ME EN 3700 Fluid Mechanics

Of particular interest was the laboratory content associated with: (1) designing experiments; (2) conducting experiments; and (3) analyzing resulting data. The demonstrated levels associated with these three components were given a rating of high, medium, low, or none. Table 4A2-1 shows the results of this assessment.

Table 4A2-1: focused analysis of coverage of experiment-related outcomes

Course	Demonstrated Level		
	Ability to design experiments	Ability to conduct experiments	Ability to analyze resulting data
ME EN 3200 Mechatronics I	None	High	High
ME EN 3200 Mechatronics I	None	High	High
ME EN 3300 Strength of Materials	Low	High	High
ME EN 3600 Thermodynamics II	None	High	High
ME EN 3650 Heat Transfer	None	High	High
ME EN 3700 Fluid Mechanics	None	High	High

The results of this assessment show that all of the junior-level laboratory components are providing opportunities for students to demonstrate ability to conduct experiments and to analyze the resulting data. However, there currently exists minimal opportunities for students to design experiments associated with these junior-level laboratory experiences. Only one experiment in ME EN 3300 Strength of Materials focuses on experimental design. In this experiment, students must devise a testing methodology to obtain the flexural stiffness, EI, of a boat oar. No other experiences in design of experiments are currently present in any of the other 3000-level laboratory experiences.

Indirect Assessment of Outcome 2

EBI Survey Assessment of Outcome 2

Three questions on the EBI survey of graduating seniors are directly related to this outcome:

To what degree did your engineering education enhance your ability to apply your ...

- ... ability to design experiments?
- ... ability to conduct experiments?
- ... ability to analyze and interpret data?

In 2014, phrasing changed as indicated in the figure captions. Scores ranged from 1 (not at all) to 7 (extremely). The responses are shown in Figures 4A2-4 through 4A2-6.

The average response from University of Utah ME students from these three questions are comparable to those for the “Select Six” institutions, the Carnegie Class schools, and for all EBI client schools. The lowest University of Utah scores up through 2013 (i.e., predating the EBI wording changes) were received for “design experiments” and “conduct experiments” whereas the highest scores (between 5.4 and 6.0) were received for “analyze and interpret data.” These

results, which reinforce the findings from the direct assessment of the junior-level laboratory courses, suggest that our students are experiencing fewer opportunities to design and conduct experiments in comparison to analyzing data. While the EBI scores suggest that the outcome is met, the moderately acceptable strength of compliance (as well as a generally downward trend in the scores) triggers (in part) the corrective actions discussed in Section B ACTIONS 16 and 18, specifically 1) the introduction of a new sophomore-level statistics course that will include a large unit on the design of experiments, and 2) a standalone Thermal-Fluids and Energy Systems (TFES) lab that will include instruction and exercises related to the design of experiments.

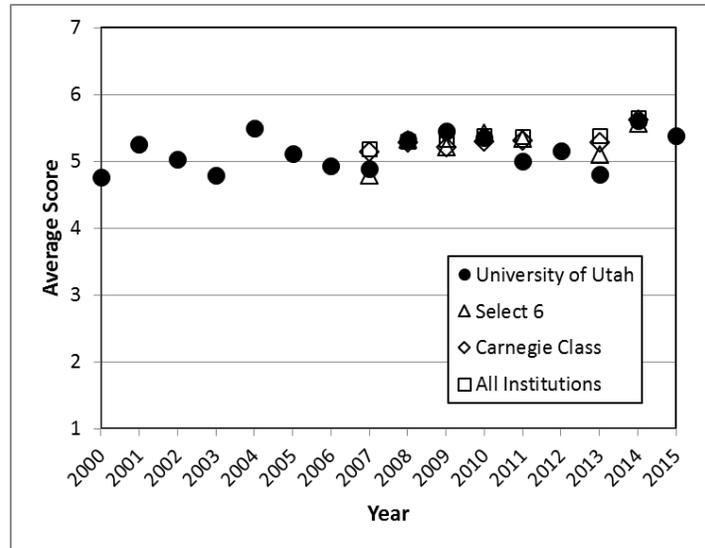


Figure 4A2-4: Response to EBI Survey Question: “I am confident that I can design experiments”

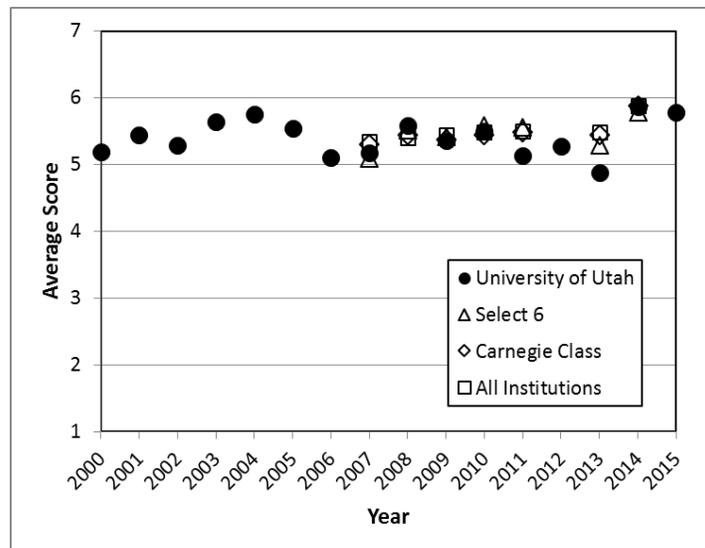


Figure 4A2-5: Response to EBI Survey Question: “I am confident that I can conduct experiments”

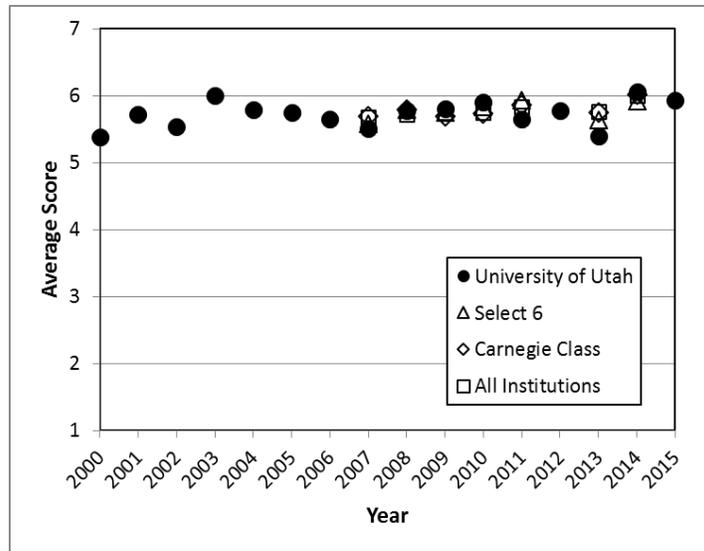


Figure 4A2-6: Response to EBI Survey Question: “I am confident that I can analyze and interpret data”

Departmental Exit Interview Assessment of Outcome 2

One question on the ME departmental exit survey relates to this outcome: “Development of my ability to design experiments, analyze and interpret data.” Figure 4A2-7 show the results obtained from this question.

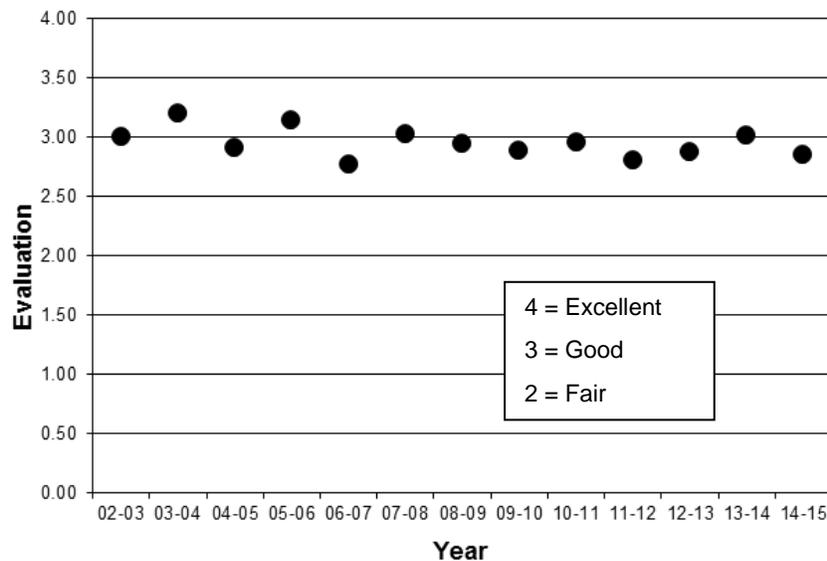


Figure 4A2-7: Response to Exit Interview Question: Rate the “development of my ability to design experiments, analyze and interpret data”

The responses received from this exit survey question indicate that students are generally satisfied with the development of their ability to “design experiments, analyze and interpret

data.” However, scores from this question range from a high of 3.2 to a low of 2.8. This range is observed to be below that received from most exit survey questions, indicating that there is less student satisfaction associated with this matter than with other aspects of the program. Based on comments from students at the Spring 2015 Exit Interview Breakfast, students feel that they do not do any real design of experiments, and that some labs are viewed merely as exercises in number crunching. Coupled with the responses received from the EBI survey, these results suggest that improvements in laboratory experiences (detailed in Section B ACTION 16) are needed to develop students’ ability to design and conduct experiments.

OUTCOME 3: DESIGN A SYSTEM/COMPONENT/PROCESS

Prior to graduation, each student in the University of Utah Mechanical Engineering Bachelor of Science Program will demonstrate the ability to design a mechanical engineering system, component, or process for achieving a desired goal.

Summary of Assessment:

The current assessment data indicate that ME students are successfully demonstrating the ability to design a system, component or process. All students are required to participate in the design of both an autonomous robot during their junior year and a capstone design project during their senior year. Assessment of these two design experiences indicates that students are satisfying this outcome. Indirect assessment using two student surveys at the time of graduation also suggests that students are receiving the education and experience to design a system, component, or process.

Recommended Action:

There appears to be no issue regarding this outcome that requires immediate action.

Direct Assessment of Outcome 3

Assessment of ME EN 3210 Robots and Controllers for Outcome 3

Students work in teams in ME EN 3210 Mechatronics II on a multidisciplinary project involving design, manufacturing, mechanisms, electronics, and programming. Each team typically designs and builds an autonomous or teleoperated robot that can accomplish specified tasks in an end-of-semester competition. The students receive a grade for their robot controller based on a rubric that includes the following items: satisfies objectives and specifications, viability of solution, creativity of solution, quality of engineering design applied, and quality of manufacturing. Representative scores for 38 teams from Spring 2015 are shown in Figure 4A3-1 (38 teams). 66% of teams scored above 90 (high level of achievement), while an additional 18% of teams scored above 75 (acceptable level of achievement). These results indicate that students are demonstrating proficiency at designing a mechanical engineering system in the context of a junior-level mechatronics project.

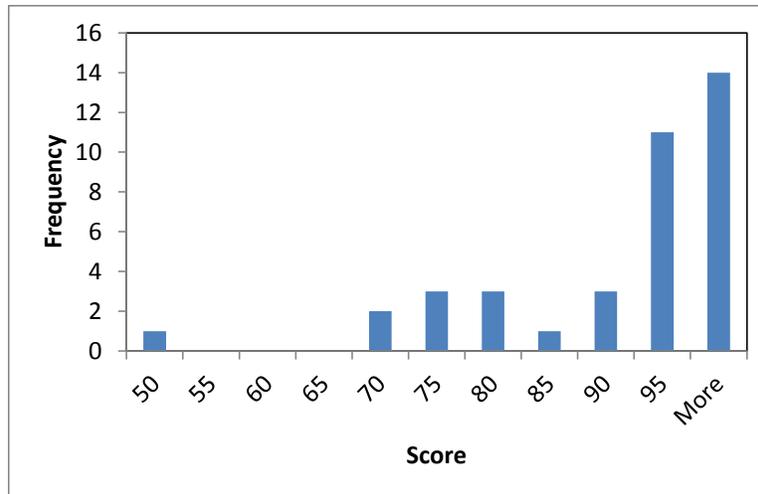


Figure 4A3-1: ME EN 3210 Robot and Controller Evaluation

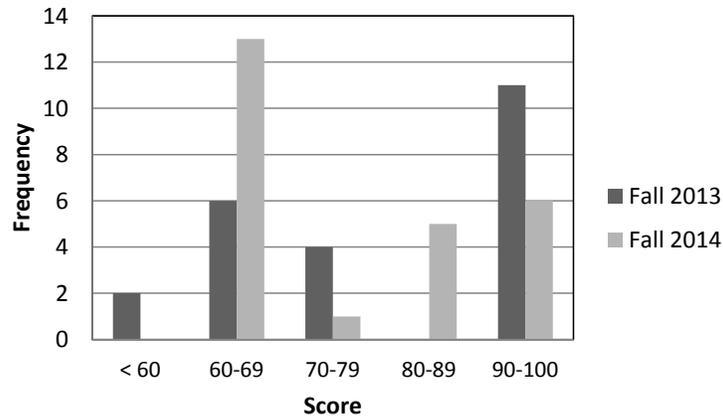
Assessment of Senior Design Critical Function Prototypes for Outcome 3

The rubric used by the panel of faculty judges to evaluate the Critical Function Prototypes at the end of ME EN 4000 Engineering Design I has three major categories: 1) Prototype motivation and planning, 2) Prototype and results, and 3) Presentation of results. Within the “Prototype and results” section, worth 50% of the overall grade, the students are evaluated on their “Reasonable execution of test plan and analysis of design” and the “Quality of [their] prototype.” The summarized scores for CFP presentations were shown under Outcome 2 above. Based on the assessment of the faculty judges, students in ME EN 4000 are able to effectively design a mechanical engineering system.

Assessment of Senior Design Projects at ME Design Day for Outcome 3

The rubric used by the faculty instructor to assess senior design teams’ Design Day posters at the end of the second semester of Senior Design contains two categories that address this outcome. These are 1) “Metrics Discussion/Achievements: Team has met all of the critical metrics and goals,” and 2) “Achievement Details: Team provides evidence and analysis of metric achievement.” Together these two criteria account for approximately 35% of each team’s Design Day grade.

Figure 4A3-2 shows the scores for this specific rubric category for two recent years (48 teams). Approximately half of the teams scored above 80%, indicating a good or excellent ability to design a mechanical engineering system. About half of the teams scored between 60% and 80%, indicating an acceptable ability level, while two teams performed at an unacceptable level. This data indicates that the students are not performing as well as they should and improvement is needed. Based on the instructor’s feedback, as well as the team from Boeing (see below), the primary concern seems to be that many teams are not communicating clearly how their design relates to metrics. This aspect of good design will be emphasized more in the Senior Design courses in the upcoming years.



**Figure 4A3-2: ME EN 4010 Design Day Evaluation
“Metrics Discussion and Achievement Details”**

Representing industry, a team from Boeing attends Design Day to help judge the Capstone Projects. Boeing has reviewed projects at Design Day at least the last four years. In 2013 and 2014 they did not provide a formal summary, but they informally shared their impressions with the instructor. Additionally, Boeing chose 1st, 2nd, and 3rd place awards for the best projects. While their assessment is more qualitative in nature, they have provided verbal feedback that the students demonstrate effective design. However, one visitor from Boeing in Spring 2015 provided the following feedback, which indicates that perhaps our students need to do a better job of communicating objectives and performance in a concise way.

From: Ledesma, James P [<mailto:james.p.ledesma@boeing.com>]
Sent: Monday, April 27, 2015 8:40 AM
To: Bruce Kent Gale
Subject: RE: Tour and Design Day

Glad we could participate again this year. The tour went well. Here is the feedback I gave to all the teams I reviewed. At large companies, there are times when your project lives or dies by one slide; like their posters for design day. I told them that when presenting your project you have to “sell it” and the one “slide” better have your objectives/requirements, show your metrics compared to requirements/goals, and most importantly have mitigation plans on metrics that did not meet expectations. The mitigation plans need not only cover how you will technically resolve the shortcomings, but the cost and schedule impacts. The IV project was the only project that I saw that was close to what our company would expect at a project review; that was one of the reasons we thought it was the best project this year. Hope this was helpful,
 JIM

Indirect Assessment of Outcome 3

EBI Survey Assessment of Outcome 3

One question on the EBI survey of graduating seniors is directly related to this outcome: “To what degree did your engineering education enhance your ability to design a system, component, or process to meet desired needs?” The response data given in the Figure 4A3-3 (with the caption showing the new phrasing of the question starting in 2014) are sufficiently high to indicate that students are receiving the education and experience to design a system, component, or process. Even though these scores are acceptable, the slightly lower scores than comparison institutions are triggers to inspect the parts of the curriculum, laboratory facilities, and instruction related to this outcome. See Section B: Continuous Improvement Actions.

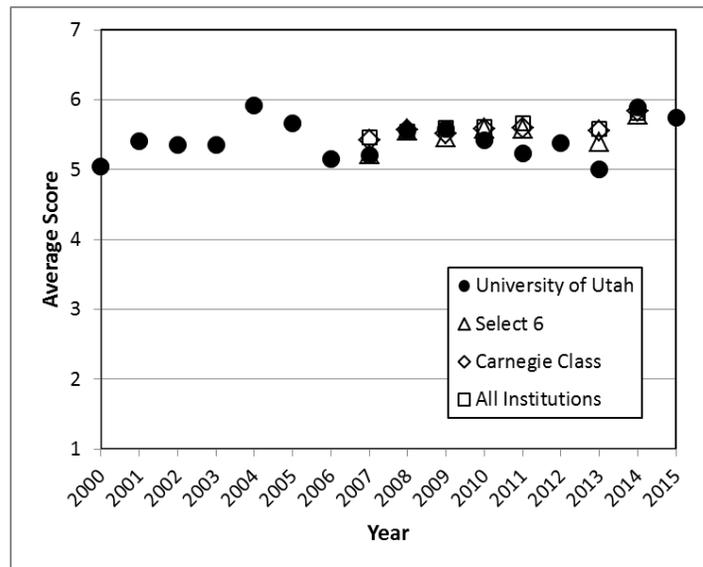
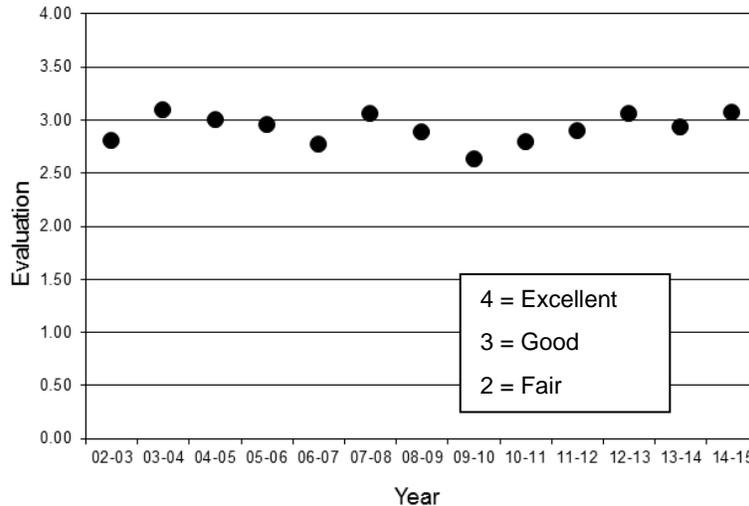


Figure 4A3-3: Response to EBI Survey Question: “I am confident that I can design a system component or process to meet desired needs”

Mechanical Engineering Exit Survey for Outcome 3

One question on this departmental exit survey relates to this outcome: “The degree to which design is integrated into the curriculum.” Figure 4A3-4 shows the response obtained from this question. Responses in four of the six years shown give an average numerical result of around 3.0, indicating a “good” response. In two of the six years, however, the average was lower (approximately 2.8). The students’ overall response indicates a generally positive opinion of the design components in the curriculum, and specifically of the Capstone Design sequence, which would have just been completed by the graduating seniors who completed this survey.



**Figure 4A3-4: Response to Exit Survey Question:
Rate “the degree to which design is integrated into the curriculum”**

OUTCOME 4: TEAMWORK IN PURSUIT OF MULTIDISCIPLINARY GOAL

Prior to graduation, each student in the University of Utah Mechanical Engineering Bachelor of Science Program will demonstrate the ability to use teamwork in pursuit of a multidisciplinary goal.

Summary of Assessment:

All assessment data indicate that the students are graduating with the ability to use teamwork in pursuit of a multidisciplinary goal. In the current curriculum, teamwork skills are taught primarily in ME EN 1000 Introduction to Mechanical Design for Engineering Systems and ME EN 4000 Engineering Design I. Student satisfaction with this aspect of their curriculum was assessed using the surveys described below. In addition, direct assessment of teamwork skills in ME EN 1000 indicates that students are able to lay the foundations for successful team experiences early in the program. Indirect assessment through the EBI survey and the departmental exit survey indicate that students are generally satisfied with their ability to function in multidisciplinary teams. Additionally, students felt that their fellow students were good team members and were very satisfied with the team experiences provided in the curriculum.

Recommended Action:

No immediate action is necessary for this outcome. However, changes to the CLEAR Program (i.e., a shift to a permanent instructor whose primary responsibility is to teach a standalone communications course) warrant close monitoring of this outcome during the next review cycle. Assessment methods should continue to be used at different stages of the undergraduate curriculum to track the development of students’ teamwork skills.

Direct Assessment of Outcome 4

Assessment of ME EN 1000 Working Agreement Assignment for Outcome 4

Since 2003, when the CLEAR Program (Communication Leadership, Ethics, And Research) was developed by the College of Engineering in collaboration with the College of Humanities, teamwork instruction and assessment have been provided by a CLEAR instructor, typically a graduate student from the Communications Department. With recent changes in CLEAR leadership and the perceived benefit of permanent instructors teaching standalone technical communications courses, teamwork and communication instruction is currently in a transitional period. The department's new CLEAR instructor (Russ Askren) continues to provide teamwork instruction in ME EN 1000 Introduction to Mechanical Design for Engineering Systems and ME EN 4000 Engineering Design I, but CLEAR-led teamwork assessment was not well sustained very far into this review cycle. Instead, graduate teaching assistants grade the ME EN 1000 Working Agreement assignment using a rubric to assess the level to which each team's working agreement specifies the following: goals, meetings, expectations, responsibilities, communication, concerns, and consequences/individual accountability.

Figure 4A4-1 shows a histogram of overall scores for the ME EN 1000 Working Agreement assignment from Fall 2014 (41 teams). Scores on this assignment were high, with all scores above 80 and 83% of teams scoring 90 or higher. While this is an early assignment in the first course in the program, these scores indicate that the students are already learning to establish effective teamwork practices. ME EN 3210 Mechatronics II and ME EN 4000/4010 Engineering Design I/II also often require team working agreements, but these are currently graded primarily for completion and not for content.

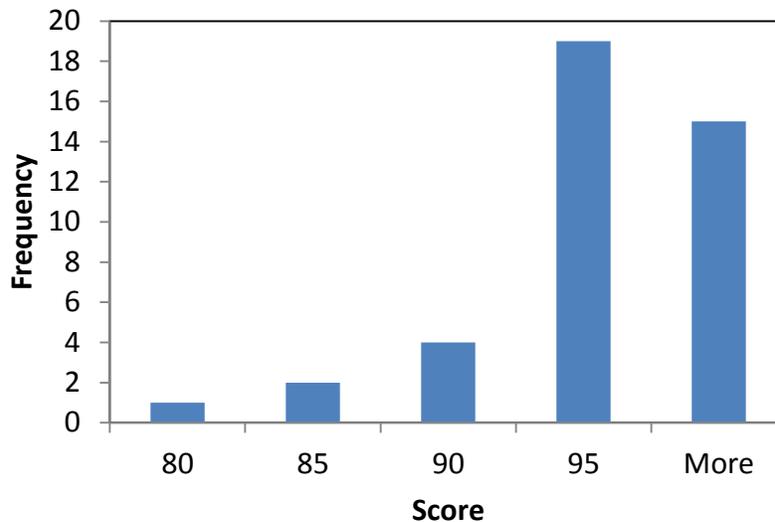


Figure 4A4-1: ME EN 1000 Working Agreement Evaluation

Indirect Assessment of Outcome 4

ME EN 4010 Team Evaluation Assessment for Outcome 4

Starting in 2009, a Team Evaluation exercise was initiated in ME EN 4010 Engineering Design II. Every team member of a student design team is required to rate how well each student met the expectations of the team. Each student evaluator is asked to rate each team member (including himself or herself) on a scale of 0 to 5. The definitions for this scale are given in Table 4A4-1. The summarized results of these team evaluations for Spring 2013 and Spring 2014 are shown in Figure 4A4-2. For 2013, 42% of the results fit into the “Excellent” category. For 2014, 56% of the results fit into the “Excellent” category, showing an improvement from 2013. For both years, over 90% are “Satisfactory” or better. This appears to be a positive indicator of the teamwork in this course.

Table 4A4-1: Rating scale definitions used by student evaluators

5	Excellent	Consistently went above and beyond; tutored teammates, carried more than his or her fair share of the load.
4	Very good	Consistently did what he or she was supposed to do, very well prepared and cooperative.
3	Satisfactory	Usually did what he or she was supposed to do, acceptably well prepared and cooperative.
2	Marginal	Sometimes failed to show up or complete tasks, rarely prepared.
1	Unsatisfactory	Consistently failed to show up or complete tasks, unprepared.
0	No show	No participation at all.

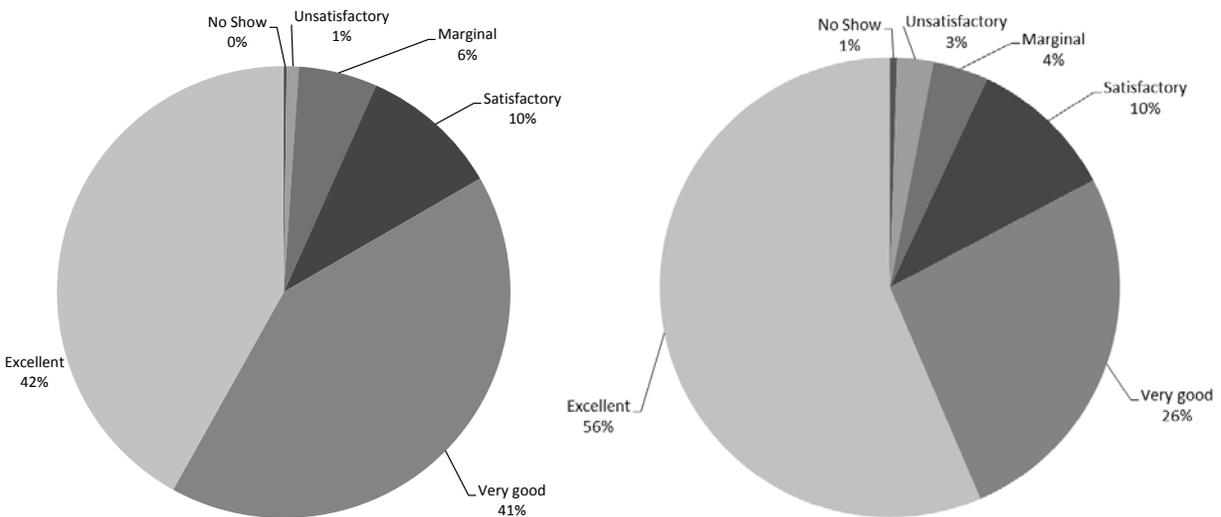


Figure 4A4-2: Engineering Design Teamwork Survey Results, Spring 2013 (left) and Spring 2014 (right)

ME EN 2450 Team Evaluation Assessment for Outcome 4

Each time that ME EN 2450 Numerical Methods for Engineering Systems is taught, a similar student survey as described above (available in the materials for the ABET evaluator) is administered to all students. Figure 4A4-3 shows representative results from Fall 2014, with the large majority of ratings being either “Excellent” or “Very Good.” These scores are corroborated by instructor and TA observations of the teams during the course of the semester, and suggest that students are developing good teamwork skills early in the program.

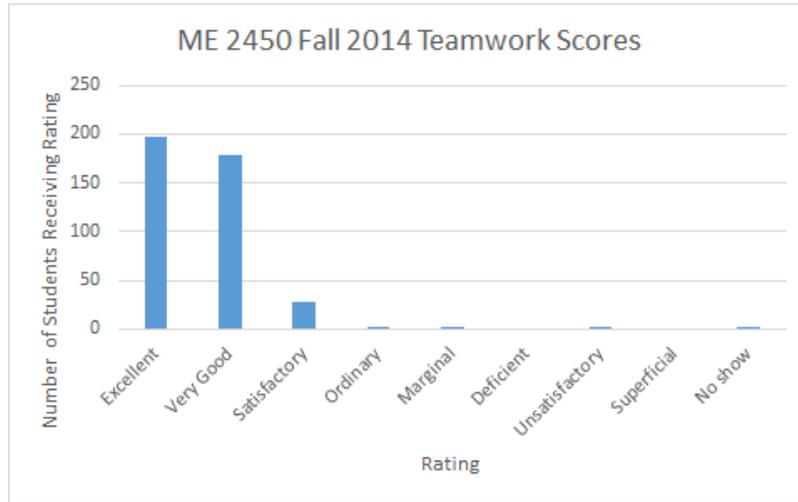


Figure 4A4-3: An example of instructor-corroborated teamwork scores

ME EN 3210 Team Evaluation Assessment for Outcome 4

Students work in teams in ME EN 3210 Mechatronics II on a multidisciplinary project involving design, manufacturing, mechanisms, electronics, and programming. Teams are formed in the Mechatronics II lab sections such that each lab section ideally has 12 students divided into three teams of four students. The project is designed such that each team of four students can break into smaller groups of two to work on parts of the project together. Ideally, we want the three teams in each lab section to support each other and learn to work collaboratively as part of a larger team with a common goal.

Team Evaluation exercises were implemented in ME EN 3210 to evaluate how well the smaller teams of four students collaborate. The exercise asked the students to fill out a teamwork evaluation form, where they were asked to indicate how they would distribute a hypothetical \$1000 bonus among their teammates, in proportion to the work each team member put in on their robot project. In order to quantify this measure of teamwork, a Teamwork Score was defined for each of the teams:

$$T_i = \left(1 - \frac{\text{stdev}(D_i)}{\text{mean}(D_i)}\right) \times 100\%, i = 1:n$$

where T_i is the teamwork score for the i^{th} team, D_i is the set of bonus data from all team members on the i^{th} team, and n is the number of teams in a given year. If all bonuses recorded for that team were equal, the standard deviation would be zero, and the team would get a perfect score of 100%. The more unequal the distributions, the lower the teamwork score.

In Spring 2013, 129 of 134 students completed the exercise for total of $n=30$ teams (Figure 4A4-4). Three teams scored 90-100%, nine teams scored 80-90%, five teams scored 70-80%, ten teams scored 60-70%, and three teams scored 50-60%. Teams with results below 70% were very concerning and triggered a need to evaluate teamwork education in the class. Analysis of course instruction indicated two potential issues: (1) Teams did not form a working agreement at the beginning of the semester and (2) teams were instructed to use survey data indicating their expertise, interests, and prior education in order to self-select their teams. In the case of (1), students did not have commonly agreed expectations and consequences for failing to meet those expectations, and as a result, the more motivated students tended to carry more of the load for the team, leading to the discrepant bonuses. In the case of (2), we found that students did not do as good of a job as hoped when forming their teams. For example, we found that some teams tended to form based upon past acquaintances, regardless of expertise, which also resulted in some teams being just former University of Utah students and others being transfer students. This made it more difficult for teams with limited experience in particular areas (e.g., programming, electronics, CAD, manufacturing, etc.) to succeed, which again resulted in one or two people on the team pushing hard to succeed and others disengaging.

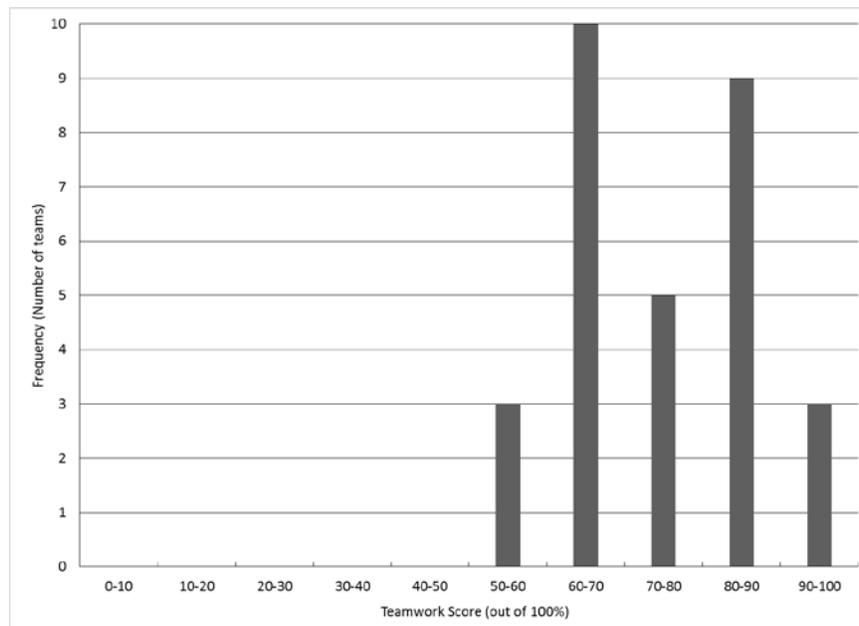


Figure 4A4-4: ME EN 3210 Teamwork Scores from 2013

In Spring 2015, several revisions were made in an attempt to improve teamwork. To address problem (2) above, teams were formed by the Teaching Assistants based upon student survey data to ensure that teams had a balanced mix of skills, interests, and educational backgrounds. In order to address (1), teams were required to form and sign a working agreement indicating expectations (developed from original CLEAR program templates), guidelines for meeting those expectations, and consequences if those expectations were not met. Teams were also advised to form area technical leads such that each person had responsibility for an aspect of the project, and then other team members were expected to help support each other throughout the semester. To ensure that responsibilities were shared, teams were also advised to proactively guard against the lone student that might try to do all of the work.

In 2015, Team Evaluation exercises were implemented again in ME EN 3210 with 168 of 169 students completing the exercise for a total of 39 teams. Spring 2015 data are shown in Figure 4A4-5. As indicated, seventeen teams scored 90-100%, fourteen scored 80-90%, five scored 70-80%, two scored 60-70%, and one scored 50-60%. This demonstrates that 7.6% of teams scored below 70%, compared to 40% in 2013, and 79.5% of teams scored 80% or higher in 2015 compared to only 40% in 2013. Of the three teams below 70% in 2015, the problem again was that one or two team members on each of these teams did not fulfill their commitment to their teams and the other team members carried their load. One of the teams admitted in their team evaluation exercise that they needed to enforce their consequences more firmly whereas the other two teams attempted to enforce their consequences, and the instructor even became involved, but the low-effort teammates still did not do enough work to satisfy their team. Many students on the successful teams, however, indicated great appreciation for their team experience as a result of these improvements.

Given these results, it is clear that teams must form written and signed team working agreements. It is also clear that teams should be composed of students with complementing expertise, interests, and educational background so that the team can easily address each aspect of the project. This team formation approach seems to work best if each Lab TA forms teams based on student survey data, although it can be challenging if student interests are not sufficiently diverse. In future offerings of the course, the students should be encouraged to enforce their team contracts and consult with their TA and instructor if problems are not resolved. Teams should also be encouraged to interact more with other teams in their lab section in an effort to further improve collaboration. For example, teams frequently struggle with programming serial communications, but that could be streamlined if the three serial communication leads in each lab section were required to meet as a group to share successes and challenges.

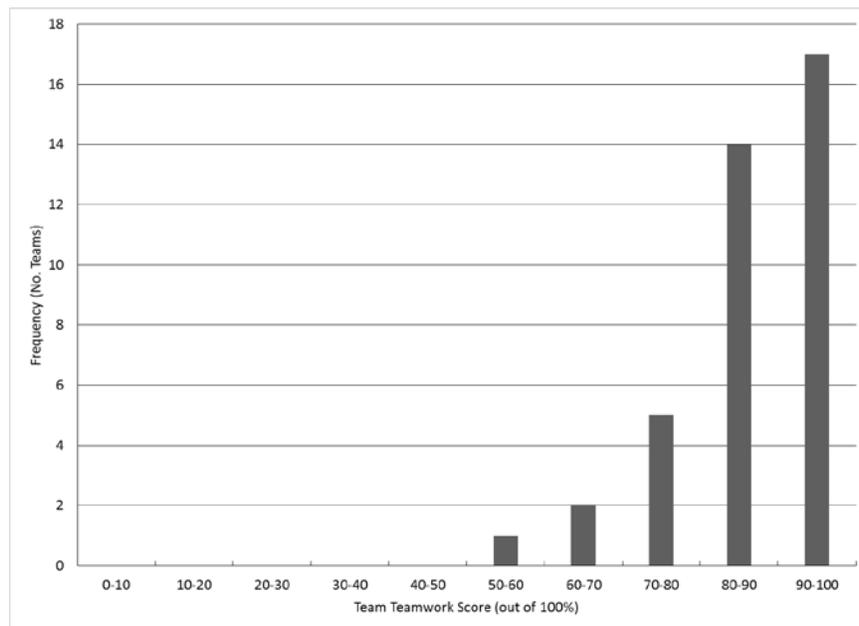


Figure 4A4-5: ME EN 3210 Teamwork Scores from 2015

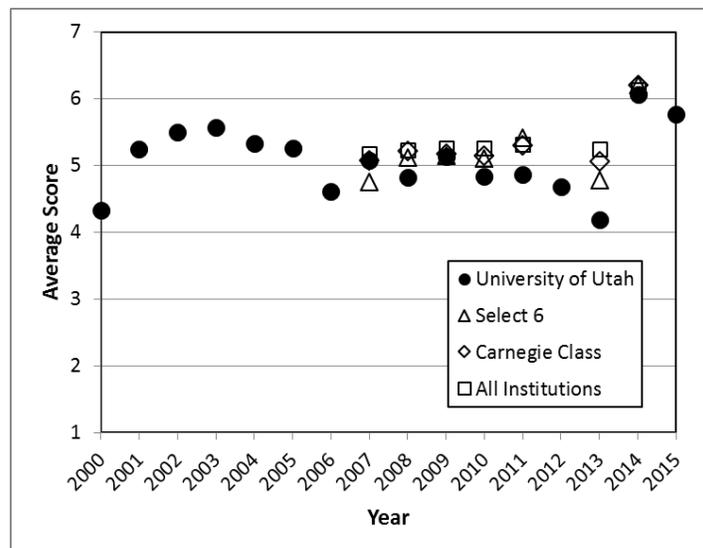
EBI Survey Assessment of Outcome 4

The EBI survey of graduating seniors includes three questions that are directly related to this outcome:

- To what degree did your engineering education enhance your ability to function on multidisciplinary teams?
- How do you rate your satisfaction with the value derived from team experiences?
- How satisfied were you with the ability of your fellow students to work in teams?

In 2014, the phrasing changed as indicated in the figure captions. The responses, from 1 (not at all) to 7 (extremely), are shown in Figures 4A4-6 to 4A4-8.

The results of the first question (Figure 4A4-6) show a fairly persistent trend for our alumni's assessment of their education in the area of multidisciplinary teams to be below scores for comparison institutions, with a noticeable dip in 2012 and 2013 (scores in 2014 and 2015 are ignored because they seem to be higher only as a result of the wording change). The scores are high enough to indicate that the department has maintained an acceptably good level of education in multidisciplinary teams, but there is definitely room for improvement, the first step of which will be to determine if it is actually the "multidisciplinary" aspect of the question that is inducing the lower scores (which we suspect will be the case given that other indirect assessments such as the senior exit breakfast consistently indicate that students are *very* satisfied with their teaming experiences). Past efforts to incorporate teaming that have established a strong culture for team-oriented projects in the department, so these scores suggest that the team projects need to include goals that are explicitly multidisciplinary.



**Figure 4A4-6: Response to EBI Survey Question:
“I am confident that I can function on multidisciplinary teams”**

The results of the second question (Figure 4A4-7) indicate that students perceive their team experiences as valuable as indicated by scores around 5.0. These scores are similar to those for all other institutions and indicate that team experiences are neither a strength nor a weakness of the program (although we reiterate that students in the department exit interview meetings have highly praised their teamwork experiences).

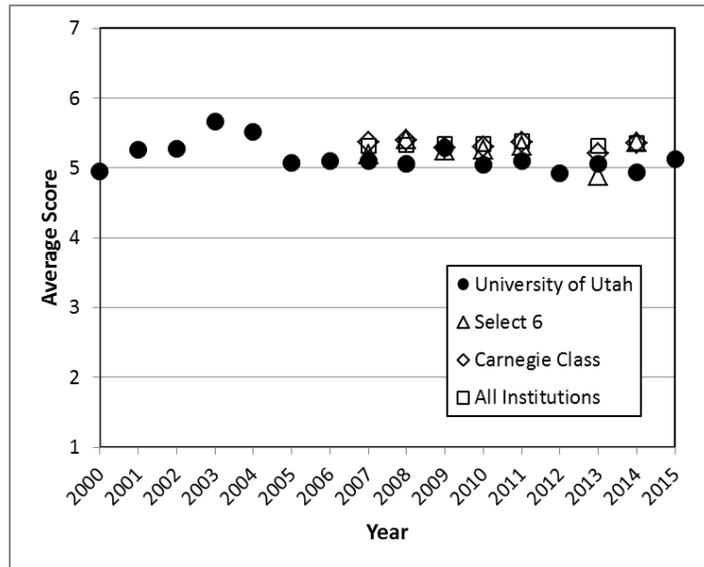


Figure 4A4-7: Response to EBI Survey Question: “How satisfied were you with value derived from team experiences?”

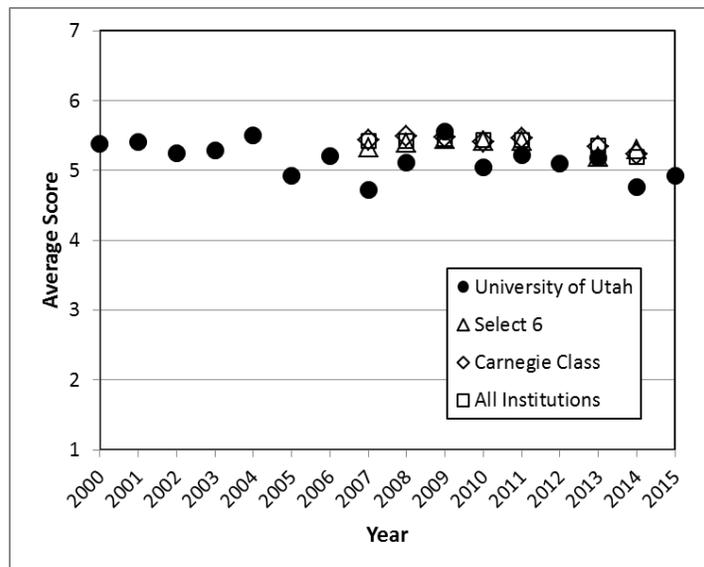
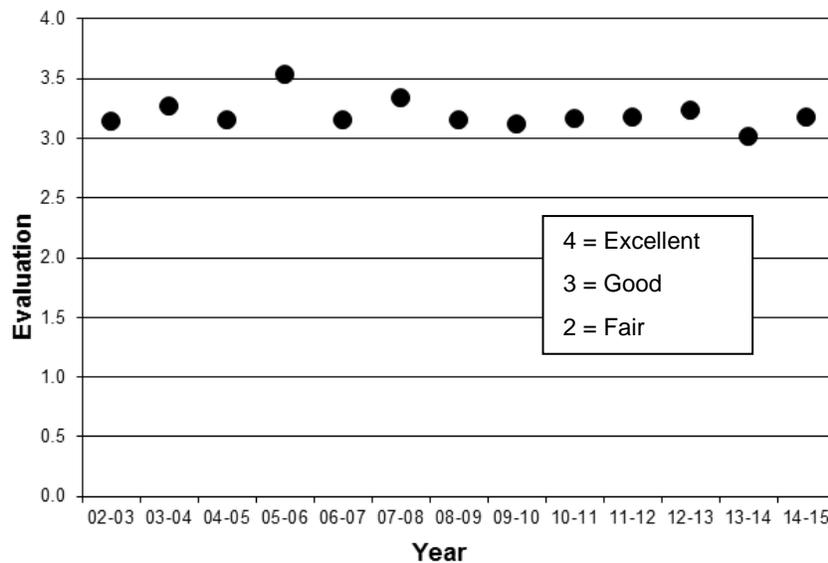


Figure 4A4-8: Response to EBI Survey Question: “Regarding your fellow students, how satisfied were you with their ability to work in teams?”

Figure 4A4-8 shows the results of the third question, for which scores around 5.0 indicate that students perceive their teammates as having good teaming skills. These scores are similar to those for all other institutions and again indicate that teamwork is neither a strength nor a weakness of the teaming experiences in the department. Since in any educational endeavor, most students' teaming abilities as well as their abilities to assess teaming skills will rise and fall as a group, less fluctuation might be expected as compared to the previous question. Thus, this measure may not be useful for assessing the departments teaming experiences other than to potentially identify a major issue flagged by a significant deviation from the average score of ~5.0.

Mechanical Engineering Exit Survey Assessment of Outcome 4

One question on the ME departmental exit survey relates to this outcome: "Opportunity to learn and apply team working skills." Figure 4A4-9 shows the results obtained from this question. Over the last six academic years, the average score has remained between 3.0 and 3.5. Since most of these students had just completed the Capstone Design sequence, this may reflect primarily on the teaming activities related to that course.



**Figure 4A4-9: Response to Exit Survey Question:
Rate "your opportunity to learn and apply team working skills"**

ABET Notebook Assessment of Outcome 4

In an assessment of content within all of the undergraduate courses, nine required courses have been designated as having team-oriented design activity at a high level (i.e., an essential component or a frequent activity). An additional four required courses have at least some level of teamwork activity. There are also over a dozen electives at the 5000 level that have been designated as having at least some level of teamwork activity. A survey of these projects and teaming exercises indicate a sufficient level of teaming activities and a wide range of teaming methods, which help students develop broad skills in this area.

OUTCOME 5: IDENTIFY, FORMULATE, AND SOLVE MECH. ENGR. PROBLEMS

Prior to graduation, each student in the University of Utah Mechanical Engineering Bachelor of Science Program will demonstrate an ability to identify, formulate, and solve mechanical engineering problems.

Summary of Assessment:

Students are clearly demonstrating the ability to solve mechanical engineering problems through the requirement that they pass the Fundamentals of Engineering (FE) examination prior to graduation. This exam is comprehensive in nature and requires students to solve specific problems characteristic of mechanical engineering. Further, all students must successfully complete a Capstone Design Project that requires them to identify, formulate, and solve a range of problems specific to their project. While these projects are more focused than the FE exam, students demonstrate particular proficiency in an area of interest to them. Indirect assessments through both the EBI survey and the departmental exit survey further indicate proficiency in this outcome.

Recommended Action:

No issues associated with this outcome require immediate action.

Direct Assessment of Outcome 5

Fundamentals of Engineering Examination Assessment of Outcome 5

The questions on the FE exam are designed to test all fundamental aspects of the student's engineering capability. On the general subject exams, many areas are included that are core to mechanical engineering problem solving capabilities: statics, dynamics, solid mechanics, thermodynamics, material science, strength of materials, fluid mechanics, economics, etc. These questions require the student to solve engineering problems related to the aforementioned areas. As a graduation requirement, students must pass (not just take) the FE exam, so this 100% pass rate is strong evidence of achievement of this outcome.

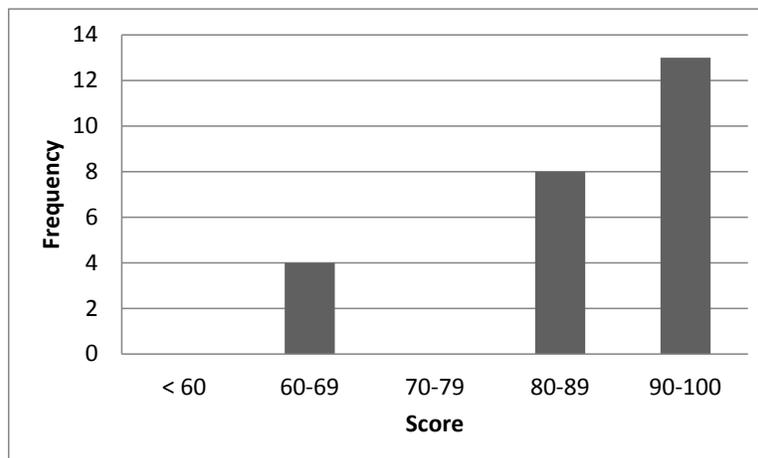
Assessment of Senior Design Critical Function Prototypes for Outcome 5

The rubric used by the panel of faculty judges to evaluate the Critical Function Prototypes at the end of ME EN 4000 Engineering Design I has three major categories: 1) Prototype motivation and planning, 2) Prototype and results, and 3) Presentation of results. The "Prototype motivation and planning" section, worth 30% of the overall grade, addresses the problem identification and formulation aspects of this outcome, while the subcategory "Reasonable execution of test plan and analysis of design" within the "Prototype and results" section relates to problem solving. The summarized scores for CFP presentations were shown under Outcome 2 above. Based on the assessment of the faculty judges, students in ME EN 4000 are able to effectively identify, formulate, and solve mechanical engineering problems in the context of a design project.

Assessment of ME EN 4010 Design Reviews for Outcome 5

During ME EN 4010 Engineering Design II, the second half of the Senior Design sequence, each team is required to give three design review presentations. The faculty instructor assesses these presentations. A rubric is used for grading, which includes “Current progress – Design Methodology: Clear, concise and logical link from customer needs to metrics to a test plan or calculations and results.” In this category, students are assessed on their ability identify engineering problems based on customer needs, translate to specifications, and analyze the problem to meet specifications.

Figure 4A5-1 shows the scores for this specific rubric category for Fall 2014 (25 teams). The vast majority (84%) of teams are demonstrating an ability to follow proper design methodology to identify, formulate, and solve mechanical engineering problems. The remainder demonstrate an acceptably ability to follow proper design methodology.



**Figure 4A5-1: ME EN 4010 Design Review 3 Evaluation
“Design Methodology”**

Indirect Assessment of Outcome 5

EBI Survey Assessment of Outcome 5

The EBI survey of graduating seniors includes three questions that are directly related to this outcome:

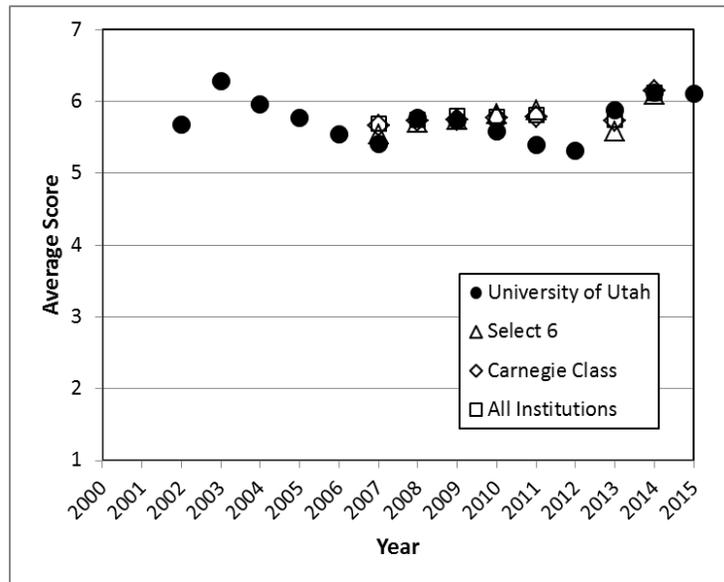
To what degree did your engineering education enhance your ability to...

- ... identify engineering problems?
- ... formulate engineering problems?
- ...solve engineering problems?

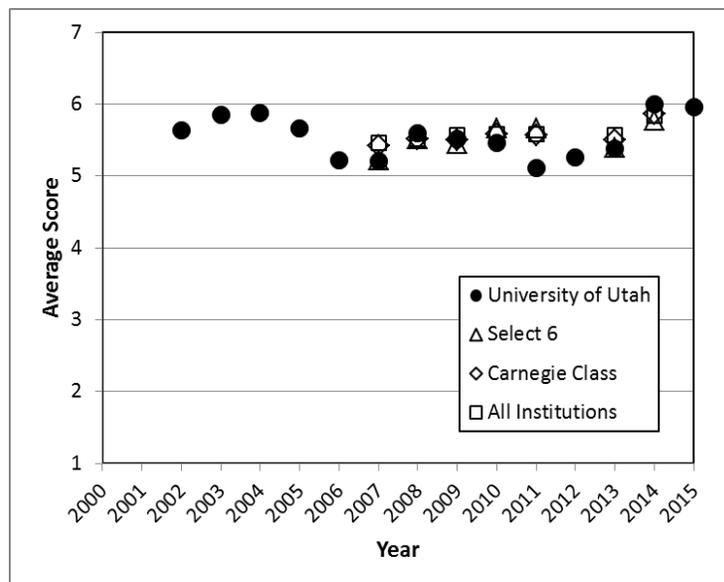
Rephrasing in 2014 is reflected in the captions of Figures 4A5-2 to 4A5-4, scored from 1 (not at all) to 7 (extremely).

The average responses from University of Utah ME students from all three questions (Figures 4A5-2 to 4A5-4) are very similar to those for the “Select Six” institutions, the Carnegie Class

schools, and for all EBI client schools. The highest University of Utah scores (between 5.6 and 6.0) were received for “solve engineering problems.” Slightly lower scores (before 2014 rephrasing of the questions) were received for both “identify” and “formulate,” with “formulate” producing the lowest scores. Although students may be experiencing fewer opportunities to identify and formulate engineering problems than simply solving engineering problems, these ratings still suggest that they consider their ability in all three aspects to be acceptable.



**Figure 4A5-2: Response to EBI Survey Question:
“I am confident that I can identify engineering problems”**



**Figure 4A5-3: Response to EBI Survey Question:
“I am confident that I can formulate engineering problems”**

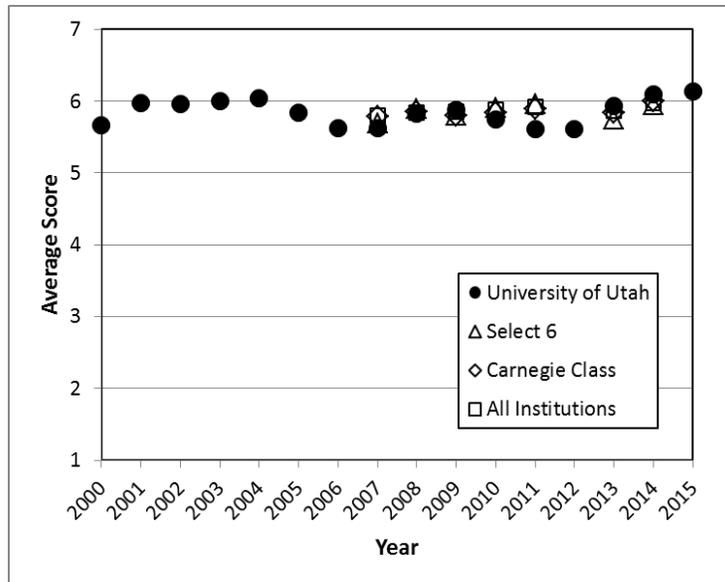


Figure 4A5-4: Response to EBI Survey Question: "I am confident that I can solve engineering problems"

Departmental Exit Survey Assessment of Outcome 5

One question on the ME departmental exit survey relates to this outcome: "Development of my ability to identify/formulate mechanical engineering problems." Figure 4A5-5 shows that the scores received from this question continue to hold steady around 3.0, which suggests that students are satisfied with the development of their ability to identify and formulate mechanical engineering problems. This result is consistent with previously described direct assessments.

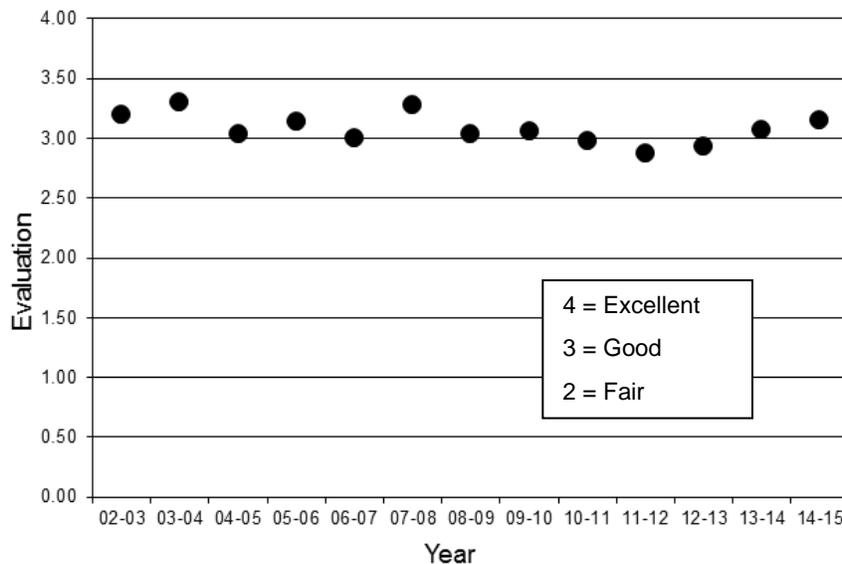


Figure 4A5-5: Response to Exit Survey Question: Rate the "development of my ability to identify/formulate mechanical engineering problems"

OUTCOME 6: PROFESSIONAL RESPONSIBILITIES

Prior to graduation, each student in the University of Utah Mechanical Engineering Bachelor of Science Program will demonstrate an understanding of the professional responsibilities of a mechanical engineer.

Summary of Assessment:

Students have scored at or near the national average on the ethics sections of the Fundamentals of Engineering (FE) exam during this review cycle. Since the FE exam is required for graduation, this result suggests that our students continue to demonstrate an understanding of the professional responsibilities of an engineer. The EBI survey of graduating seniors indicates that students credit much more of their professionalism to the general engineering education than to their design experiences. A review of ME EN 3900 Professionalism and Ethics Seminar shows that all of the seminars address these issues to some degree, with 6 of 14 seminars addressing these issues to a high degree (2014 data). In addition, students in the ME EN 3900 seminar course read *Truth, Lies, and O-Rings: Inside the Challenger Space Shuttle Disaster* by Mr. Allan McDonald, who also presents the final seminar of the semester. However, ability ratings have declined in the most recent alumni surveys, dropping below fairly steady importance ratings, indicating that students perceive a need for more instruction on professionalism and ethics.

Several curricular changes during the current review cycle have impacted ethics coverage. ME EN 4050 Concurrent Engineering II, which contained a two-week module on ethics and professionalism, was eliminated effective Spring 2013 as part of the SPIRAL curriculum changes. In the SPIRAL curriculum, ethics was covered in ME EN 1010 Introduction to the Design of Robotic Systems I, but this topic was eliminated in the revisions to the SPIRAL courses in 2013. In proposed changes to the curriculum (see Section B ACTION 16), the ME EN 3900 seminar course would be eliminated, with the intent that ethics and professionalism would be integrated into the proposed new stand-alone communications course. The Curriculum Committee feels that this will enable more consistent and intentional coverage of these topics.

Recommended Action:

Continued monitoring of this outcome is warranted based on curricular changes during the current ABET cycle and the proposed curriculum changes. The ethics and professionalism lectures and assignments in the proposed junior-level communications course should be monitored closely during the next review cycle. Additionally, incorporation of ethics/professionalism into the capstone design sequence may also be warranted.

Direct Assessment of Outcome 6

Fundamentals of Engineering Examination Assessment of Outcome 6

The program's FE exam pass rate is 100%. This exam's coverage of professional and ethical responsibilities provides strong evidence of meeting this outcome by the time of graduation.

Review of ME EN 3900 Course Material for Outcome 6

Figure 4A-5 (above) summarizes a review of outcome coverage in the ME EN 3900 Professionalism and Ethics Seminar. As shown, six of the Fall 2014 seminars addressed professionalism/ethics to a high degree, while eight seminars addressed these topics to a low degree. Thus, this 14-week seminar series continues to emphasize professionalism and ethics, providing students with an excellent exposure to these issues.

In addition to speakers who address engineering ethics, since Fall 2009 students have been required to read *Truth, Lies, and O-Rings: Inside the Challenger Space Shuttle Disaster* by Mr. Allan McDonald, who, as previously mentioned, also presents the final seminar of the semester. Quizzes on the reading are administered via Canvas. At the recommendation of Mr. McDonald, who provided a condensed reading plan, students in Fall 2014 were given an option of reading an abridged version of the book. Just over 50% of the students still chose to read the entire book.

ME EN 1010 Final Exam Question Assessment for Outcome 6

In the SPIRAL version of ME EN 1010 Introduction to the Design of Robotic Systems II, one 80-minute lecture was devoted to engineering ethics case studies. During this lecture, students were introduced to the following method for making ethical engineering decisions:

- Step 0: Come up with alternative courses of action
- Step 1: Identify the stakeholders and issues
- Step 2: Analyze alternative courses of action from the following three different perspectives: Consequences, intent, character
- Step 3: Correlate the perspectives from Step 2
- Step 4: Act

On the ME EN 1010 final exam, students were asked to apply steps 0-2 to a provided scenario. The pie graph in Figure 4A6-1 shows the distribution of scores on this question in Spring 2012, which was the last semester ethics was covered in ME EN 1010. Based on these data, 60% of the class demonstrated adequate proficiency in applying the ethics framework, scoring 70% or better on this question.

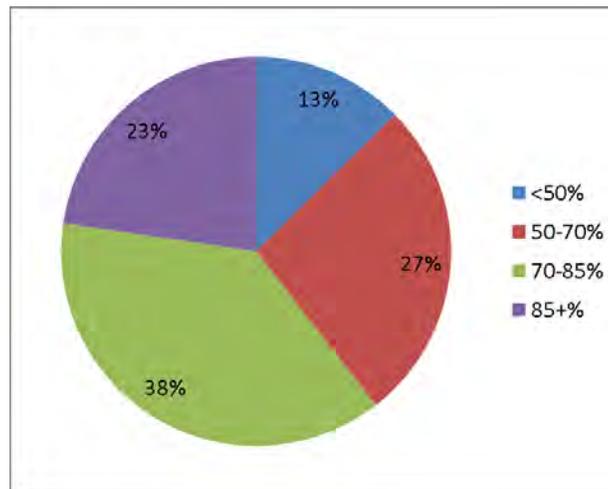


Figure 4A6-1: Direct assessment ME EN 1010 ethics final-exam question

Indirect Assessment of Outcome 6

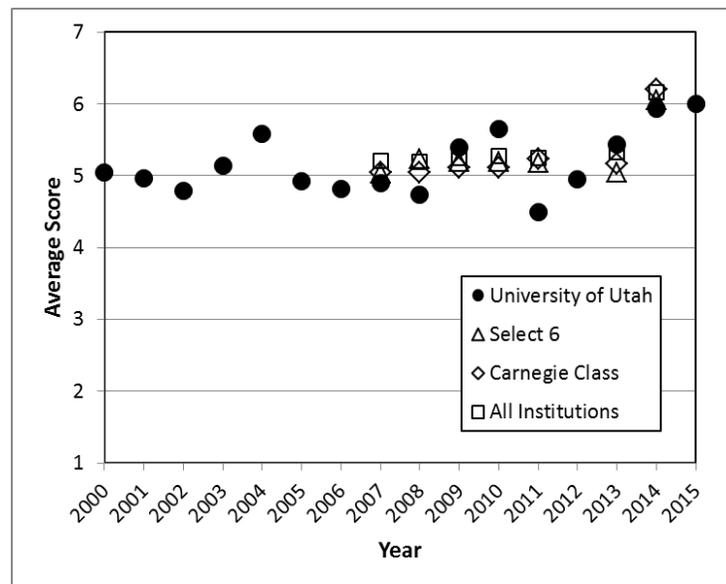
EBI Survey Assessment of Outcome 6

The EBI survey of graduating seniors includes two questions that are directly related to this outcome:

- To what degree did your engineering education enhance your ability to understand ethical responsibility?
- To what degree did your major design experience address ethical issues?

The figure caption shows rephrasing of the first question as of 2014; the second question is no longer asked (giving no data beyond 2013). The responses to these two questions are shown in the Figures 4A6-2 and 4A6-3. Scores ranged from 1 (not at all) to 7 (extremely).

The average responses from University of Utah ME students from these two questions (Figures 4A6-2 and 4A6-3) are shown to be comparable to those for the “Select Six” institutions, the Carnegie Class schools, and for all EBI client schools. In general, scores from the first question are higher than for the second, suggesting that students credit much more of their professionalism to the general engineering education than to their specific capstone design experience.



**Figure 4A6-2: Response to EBI Survey Question:
“I am confident that I can understand ethical responsibility”**

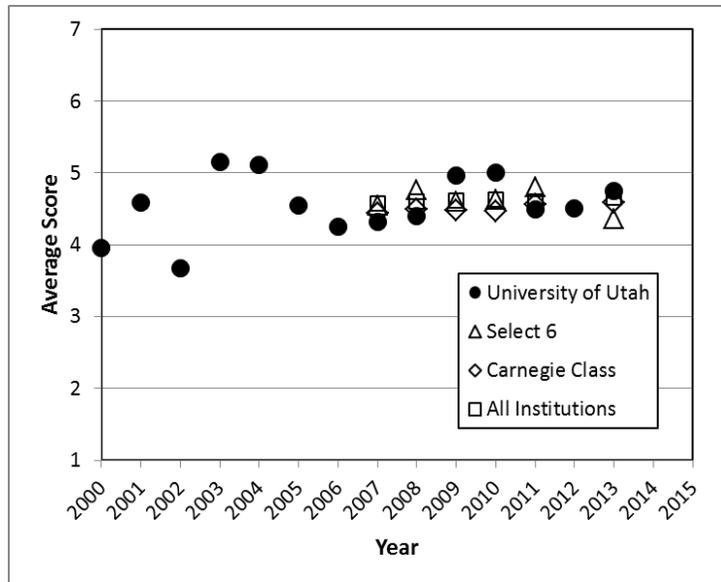


Figure 4A6-3: Response to EBI Survey Question: “To what degree did your major design experience address ethical issues?”

Departmental Alumni Survey Assessment of Outcome 6

The departmental alumni survey asks respondents (three to five years after graduation) to rate both the importance of and their ability to recognize professional and ethical responsibility, where 1 is “not important or poor” and 4 is “very important or excellent.” Figure 4A6-4 shows that in the two most recent surveys, Alumni ranked the importance higher than their ability of the job, with an ability rating around 3.0. Due to the recent decline in ability scores, this outcome will be monitored closely during the next review cycle.

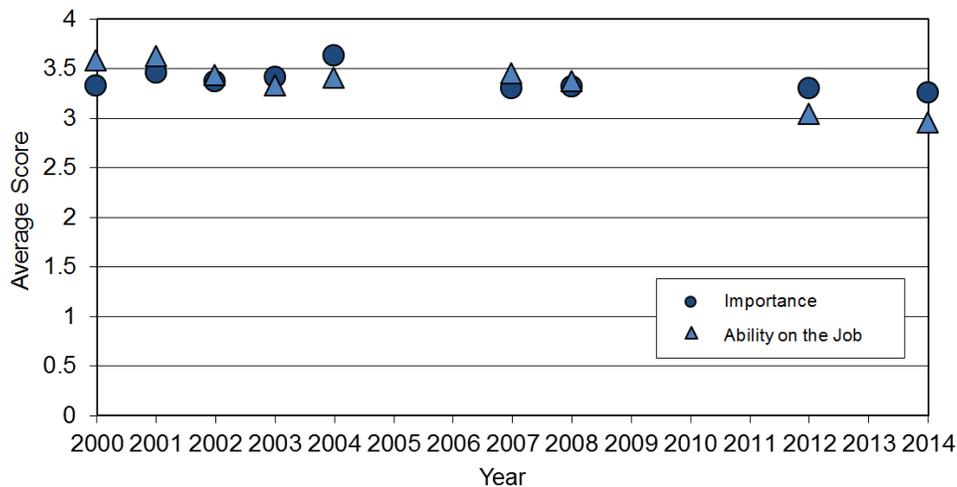


Figure 4A6-4: Response to Alumni Survey Question: “Rate the importance of and ability to recognize professional and ethical responsibility”

OUTCOME 7: EFFECTIVELY COMMUNICATE IN WRITTEN REPORTS AND MEMOS

Prior to graduation, each student in the University of Utah Mechanical Engineering Bachelor of Science Program will demonstrate the ability to effectively communicate technical information in written reports and memos.

Summary of Assessment:

Direct assessment of writing quality indicates that graduating students are demonstrating that they are able to communicate effectively through technical writing. Indirect assessment from graduating seniors via the EBI survey and departmental exit survey indicates that students are generally satisfied with the development of their writing skills.

Recommended Action:

While there does not appear to be an issue regarding achievement of this outcome, Section B explains several adjustments in the logistics and sequencing of communication instruction (see ACTIONS 16 and 17).

Direct Assessment of Outcome 7

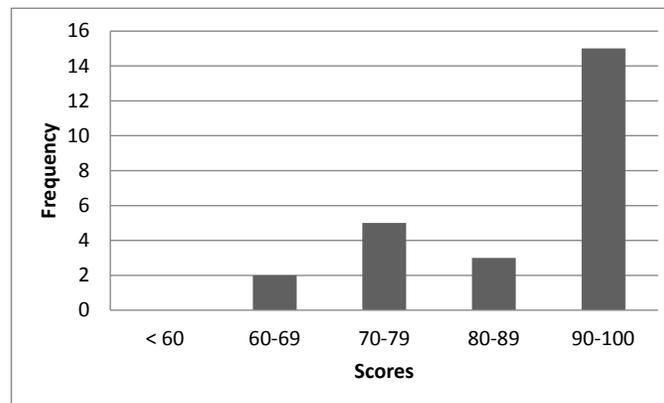
Assessment of Student Work Using CLEAR Assessment Tools for Outcome 7

As previously mentioned, the CLEAR Program (originally developed in 2003) has undergone leadership changes that have affected its structure for bringing together faculty and students from the Colleges of Humanities and Engineering to enhance undergraduate engineering education. Through this program, students continue to receive instruction on various writing topics and genres. Specifically, students learn how to prepare various documents with attention to audience and purpose. Topics include audience adaptation, structure and organization, research, use of language, incorporation of images, and attention to genre characteristics. Students receive instruction and practice producing memos, lab reports, proposals, formal reports, summaries, and technical instructions, among other types of writing. They also learn how to effectively conduct formal peer review of others' work. In comparison to the previous ABET review cycle, the CLEAR program currently provides a diminished share of direct assessment of Outcome 7, but some of the assessment tools originally developed by the CLEAR program continue to be applied in a relatively ad hoc fashion by the course instructors. While direct examination of student work demonstrated in collected sample memos and reports shows that the outcome is met, the strength of compliance would be much improved through restoring the more structured instruction and rubric-based independent direct assessment that had been applied by CLEAR in the past. It is also noted that, while the CLEAR program provides guides to good writing, students would benefit from involvement of CLEAR in detailed proofreading of student work so that students receive a greater degree of feedback. Direct assessments that had been previously provided by CLEAR staff to Design Day reports and posters have likewise not been sustained, and it is strongly recommended that these activities be resumed to strengthen the degree to which students meet Outcome 7.

Assessment of Senior Design Final Report for Outcome 7

As part of Senior Design, each team must prepare and submit a comprehensive final report on their design project. These reports are graded by both the instructor of ME EN 4010 Engineering Design II and the teams' project advisors. The report is graded against several criteria. One rubric criterion is "Report is clear, concise, and complete. Report is organized logically and easy to read. All sections are present and there is no needed but missing information. Report is not overly verbose. Figures are relevant, clear, and properly annotated." This rubric criterion directly assesses the students' ability to communicate in written reports.

Figure 4A7-1 summarizes the grades for this rubric category for Fall 2014 (25 teams). 72% of design teams demonstrated a good or excellent ability to communicate effectively through a written report. 28% were at a satisfactory level. This data indicates that the Senior Design students are capable of communicating clearly through written reports.



**Figure 4A7-1: ME EN 4010 Final Report Evaluation
"Report Organization"**

The overall grade for the report is also indicative of the students' ability to write effectively. Figure 4A7-2 summarizes the overall grades for the final report for Fall 2014. 80% of the final grades were at a score of 80 or above indicating a good or excellent ability to write a design report. The remaining 20% were in an acceptable range.

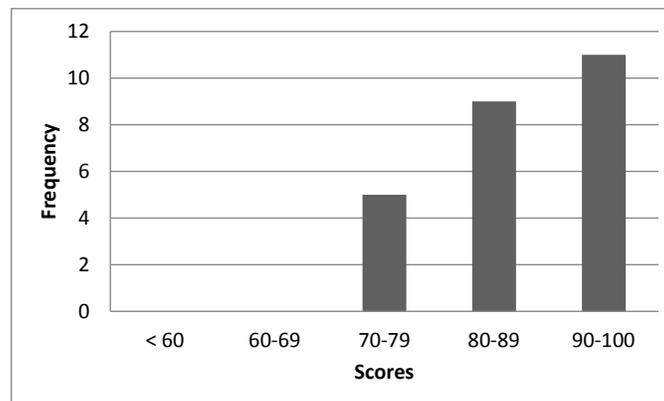


Figure 4A7-2: ME EN 4010 Final Report Overall Scores

Indirect Assessment of Outcome 7

EBI Survey Assessment of Outcome 7

The EBI survey of graduating seniors includes one question that is directly related to this outcome:

- To what degree did your engineering education enhance your ability to communicate using written progress reports?

The average responses, from 1 (not at all) to 7 (extremely), are shown in the figure below.

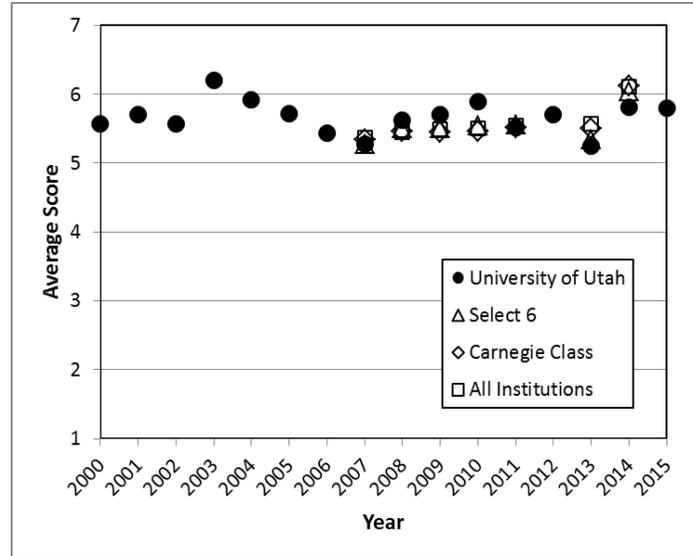
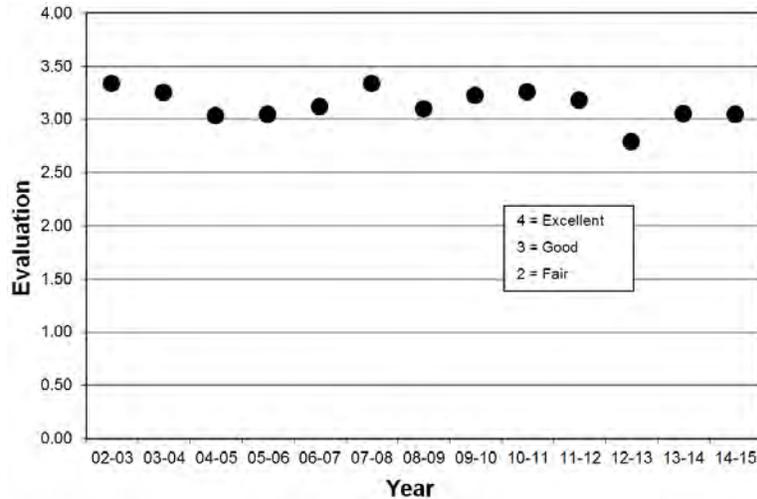


Figure 4A7-3: Response to EBI Survey Question: “To what degree did your engineering education enhance your ability to communicate using written progress reports?”

As shown in Figure 4A7-3, The average scores from University of Utah ME students are shown to meet or exceed those from the other institutional classifications given. The University of Utah scores ranged between 5.3 and 5.9, considered to be good scores for this survey. These results suggest that students are generally satisfied with the instruction received in written communication.

Departmental Exit Survey Assessment of Outcome 7

One question on the ME departmental exit survey relates to this outcome: “Development of written communication skills.” Figure 4A7-4 shows the results obtained from this question. There appears to be a slight downward trend during this review cycle. However, with the exception of the dip in 2013, scores remain above 3.0. These results suggest that students are generally satisfied with the development of their written communication skills.



**Figure 4A7-4: Response to Exit Survey Question:
Rate “your development of written communication skills”**

OUTCOME 8: EFFECTIVELY COMMUNICATE IN ORAL PRESENTATIONS

Prior to graduation, each student in the University of Utah Mechanical Engineering Bachelor of Science Program will demonstrate the ability to effectively communicate technical information in oral presentations.

Summary of Assessment:

Direct assessment of students’ oral communication skills indicates that graduating seniors are able to adequately communicate through oral presentations, although instructors of presentation-heavy courses assert there is much room for improvement. Responses received from graduating seniors on the EBI survey indicate that students are satisfied with the development of their oral communication skills. However, graduating seniors themselves have strongly indicated that oral presentation skills need better instruction.

Recommended Action:

Both direct observations and student exit feedback serve as motivation for planned restructuring of oral communication instruction, as detailed in Section B (see ACTIONS 16 and 17).

Direct Assessment of Outcome 8

Assessment of Student Work Using CLEAR Assessment Tools for Outcome 8

As previously mentioned, the CLEAR Program (originally developed in 2003) has undergone leadership changes that have affected its structure. Through this program, students continue to receive instruction on how to effectively prepare and deliver various types of presentations with

attention to presentation purposes and audiences. Instruction covers such topics as audience adaptation, effective organization, use of supporting materials, credibility, effective preparation and use of visual aids, and dynamic delivery. In addition, students are taught about various presentation genres including, but not limited to, project proposals, design reviews, instructional presentations, and update presentations. In comparison to the previous ABET review cycle, the CLEAR program currently provides a diminished share of direct assessment of Outcome 8, but some of the assessment tools originally developed by the CLEAR program continue to be applied in a relatively ad hoc fashion by the course instructors. While direct assessment of student presentations by instructors shows that the outcome is met, the strength of compliance would be much improved through restoring the more structured instruction and rubric-based independent direct assessment that had been applied by CLEAR in the past.

Senior Design Presentation Assessments for Outcome 8

As part of the Capstone Design experience, students have the opportunity to give numerous oral presentations. During ME EN 4000 Engineering Design I, each team gives two oral presentations: a Critical Function Prototype (CFP) motivation presentation part way through the semester and a final CFP presentation at the end of the semester. The panel of faculty judges assesses each team on the quality of the presentation, the oral delivery of the presentation, the design of the presentation, and the team’s professionalism, accounting for 20% of the overall grade. The summarized scores for CFP presentations were shown under Outcome 2 above. Based on the assessment of the faculty judges, students in ME EN 4000 are able to effectively communicate technical information in oral presentations.

During ME EN 4010 Engineering Design II, each team presents three design review presentations. The faculty instructor assesses each presentation on “Professionalism: Presentation is professionally prepared and presented. Team is engaged. Presentation is appropriate in length.” Figure 4A8-1 shows the scores for this specific rubric category for two recent years. 94% of teams are demonstrating an ability to communicate effectively at a high level, indicating that this outcome is being met.

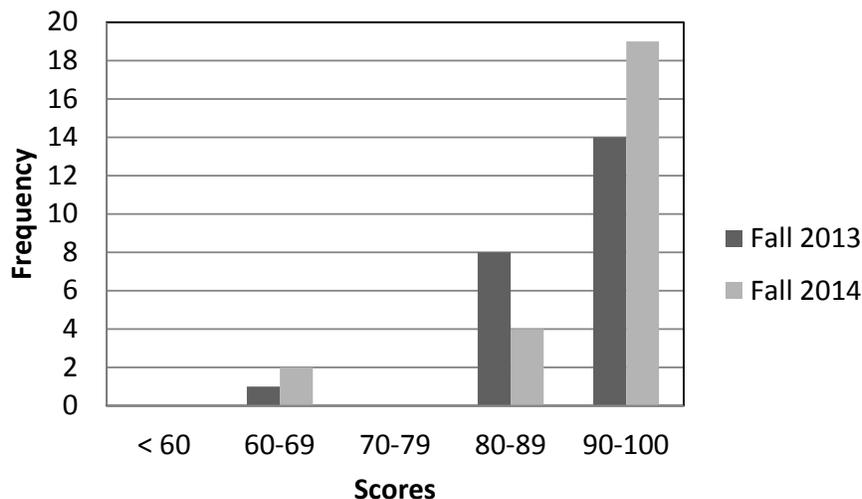


Figure 4A8-1: ME EN 4010 Design Review 3 Evaluation “Professionalism”

Finally, on Design Day, each team must present their poster to the faculty instructor and to a visiting panel from Boeing. One of the assessment criteria of the faculty instructor is “Professionalism: Presentation is professionally done and team is engaged.” Rubric results for this assessment (which are archived in the University’s course management software, Canvas) show that Outcome 8 is being met by the majority of students in Capstone Design.

Figure 4A8-2 shows the scores for this specific rubric category for two recent years. 90% of teams are demonstrating an ability to communicate effectively at a high level at Design Day, indicating that this outcome is being met.

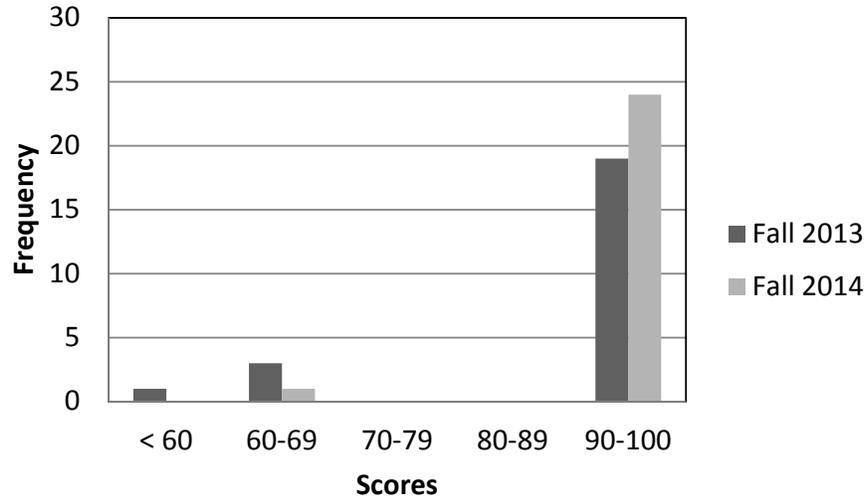


Figure 4A8-2: ME EN 4010 Design Day Evaluation “Professionalism”

Indirect Assessment of Outcome 8

EBI Survey Assessment of Outcome 8

The EBI survey of graduating seniors includes one question that is directly related to this outcome: “To what degree did your engineering education enhance your ability to communicate using oral progress reports?” The responses to this question are shown in the figure below. Scores ranged from 1 (not at all) to 7 (extremely).

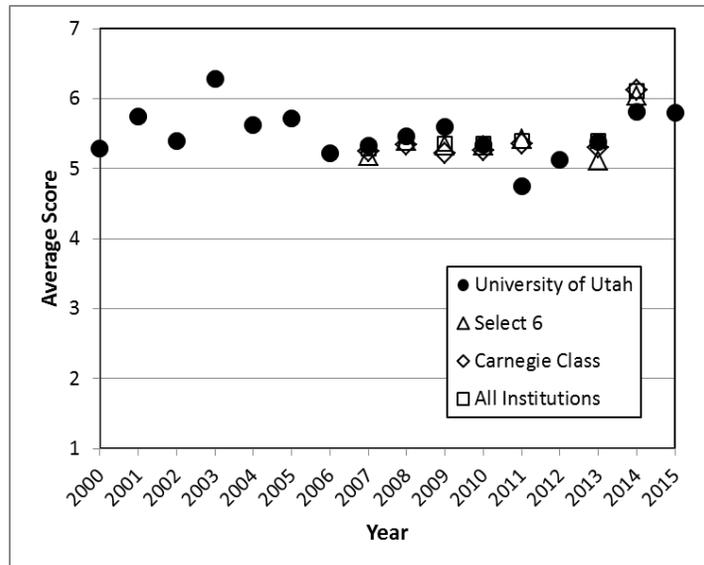
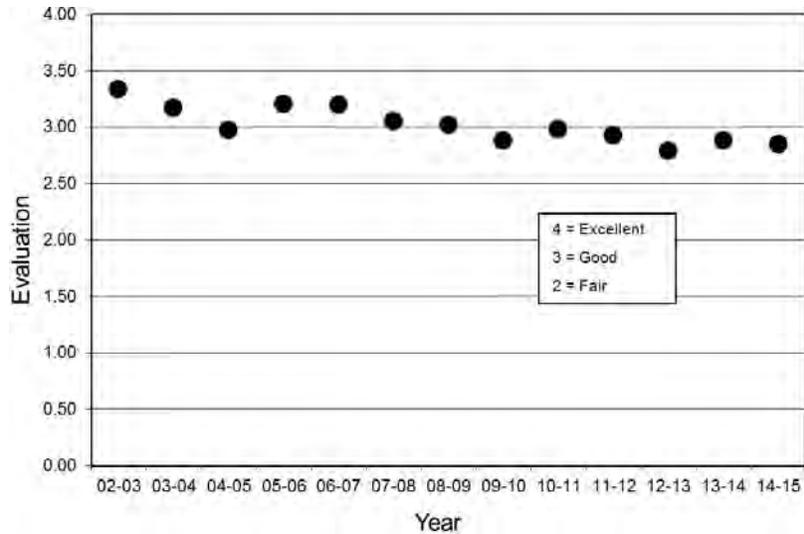


Figure 4A8-3: Response to EBI Survey Question: “To what degree did your engineering education enhance your ability to communicate using oral progress reports?”

The average responses from University of Utah ME students for this question is shown to be greater than or equal to those for the “Select Six” institutions, the Carnegie Class schools, and for all EBI client schools. The University of Utah scores ranged between 5.0 and 5.7, and vary more than for the other schools. These results suggest that students are generally satisfied with the instruction in oral communication that they have received.

Departmental Exit Survey Assessment of Outcome 8

One question on the ME departmental exit survey relates to this outcome: “Development of oral communication skills.” Figure 4A8-4 shows the results obtained from this question. The most recent scores fall near the acceptable “good” range, implying that students are generally satisfied with the development of their oral communication skills. The overall downward trend over the last two ABET review cycles has naturally triggered greater attention to oral communication skills in current curriculum development activities (see Section B).



**Figure 4A8-4: Response to Exit Survey Question:
Rate “your development of oral communication skills”**

OUTCOME 9: IMPACT OF MECH. ENGR. IN GLOBAL AND SOCIETAL CONTEXT

Prior to graduation, each student in the University of Utah Mechanical Engineering Bachelor of Science Program will demonstrate the broad education to understand the impact of mechanical engineering solutions in a global and societal context.

Summary of Assessment:

The University’s General Education and Bachelor’s Degree requirements include liberal education courses designed to challenge students to think about the world from various perspectives and develop skills that will enable them to work with diverse groups of people and help them understand and address global issues. In addition to specific content criteria, these courses must also satisfy at least one learning outcome related to personal and social responsibility. Within the mechanical engineering program, ME EN 3900 Professionalism and Ethics Seminar is the only course that addresses this outcome with a high level of activity (8 of 14 seminars in Fall 2014), but one third of the required ME courses report some activity related to this outcome. Results obtained from the EBI survey of graduating seniors indicates that students are receiving their exposure to this outcome more from their liberal education or general engineering courses than from their capstone design projects, suggesting that this outcome should be given more emphasis in the capstone design projects.

Recommended Action:

Further incorporation of this outcome into the capstone design sequence should be explored.

Direct Assessment of Outcome 9

General Education Council Review of Courses with General Education and Bachelor's Degree Designations for Outcome 9

While the Department of Mechanical Engineering does not keep course notebooks for liberal education courses taken by ME students, the courses with General Education and Bachelor's Degree designations are rigorously reviewed by the University's General Education Council, which makes recommendations to the Undergraduate Council. The College of Engineering has faculty representation on both of these bodies. Most relevant to Outcome 9 are the following designations: Humanities (HF), Social/Behavioral Science (SF), Diversity (DV), and International Requirement (IR). More details about the content criteria for these designations can be found on the University website (<http://ugs.utah.edu/gen-ed-reqs/>) or in Criterion 5 of this Self-Study document. In addition to meeting specific content criteria, the courses must also satisfy at least one of the following Personal and Social Responsibility Learning Outcomes:

- Civil engagement (local and global)
- Intercultural knowledge and competence
- Ethical reasoning
- Foundations and skills for lifelong learning

Courses with General Education and Bachelor's Degree designations are reviewed every five years. The course syllabus as well as sample student work are provided by the home department to support the fulfillment of the content criteria and the selected Learning Outcomes.

Review of ME EN 3900 Course Material for Outcome 9

Figure 4A-5 (above) summarizes a review of outcome coverage in the ME EN 3900 Professionalism and Ethics Seminar. Although the main focus of this course is on professionalism and ethics, invited speakers often focus on other topics including the impact of mechanical engineering solutions in a global and societal context. As shown in Figure 4A-5, three of the Fall 2014 seminars addressed this outcome to a high degree, while five seminars addressed this outcome to a low degree. Thus, this 14-week seminar series continues to provide students with a moderate exposure to the impact of engineering solutions in a global and societal context.

Indirect Assessment of Outcome 9

EBI Survey Assessment of Outcome 9

The EBI survey of graduating seniors includes five questions that are considered relevant to this outcome:

- To what degree did your engineering education enhance your ability to understand the impact of engineering solutions in a global/societal context?
- To what degree did your major design experience address environmental issues?
- To what degree did your major design experience address sustainability issues?
- To what degree did your major design experience address health and safety issues?
- To what degree did your major design experience address social issues?

The figure caption shows rephrasing of the first question as of 2014; the remaining questions are no longer asked (giving no data beyond 2013). Note that while the first question relates directly to the stated outcome, the remaining four questions address components of this outcome as related to the capstone design project. The responses to these five questions are shown in Figures 4A9-1 through 4A9-5. Scores ranged from 1 (not at all) to 7 (extremely).

Scores from the first question (Figure 4A9-1) range between 4.3 and 5.3 (prior to the change in phrasing) for University of Utah students, and are sometimes higher and sometimes lower than the scores from the other educational institutions participating in the survey. In general, lower scores were received for the remaining four questions that address the capstone design project (Figures 4A9-2 through 4A9-5). Of these four, the highest scores were received for “health and safety issues” (between 4.5 and 5.2) and the lowest scores were received for “environmental issues” and “social issues” (between 3.6 and 4.9). While these scores are comparable (and in many cases greater than) those from the other educational institutions, they suggest that these issues are not receiving adequate attention in the Capstone Design Projects.

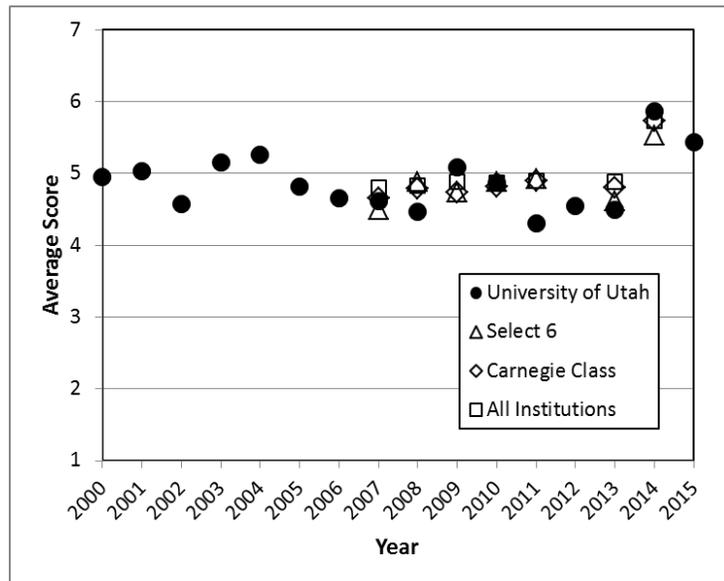
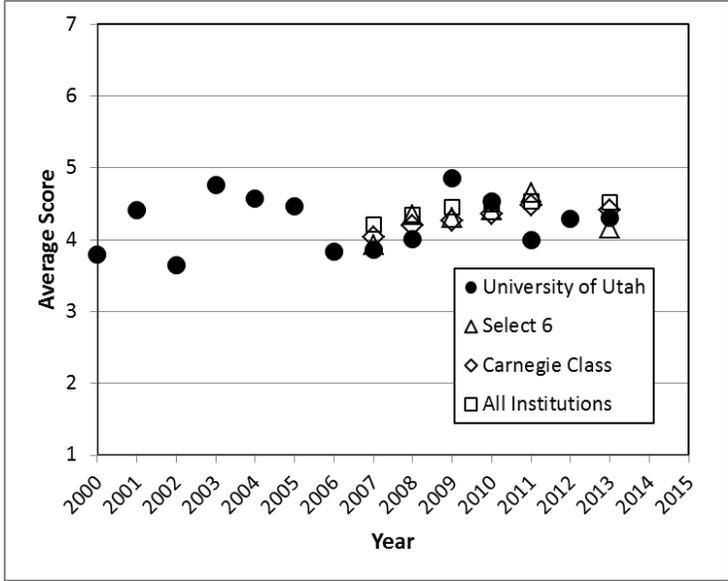
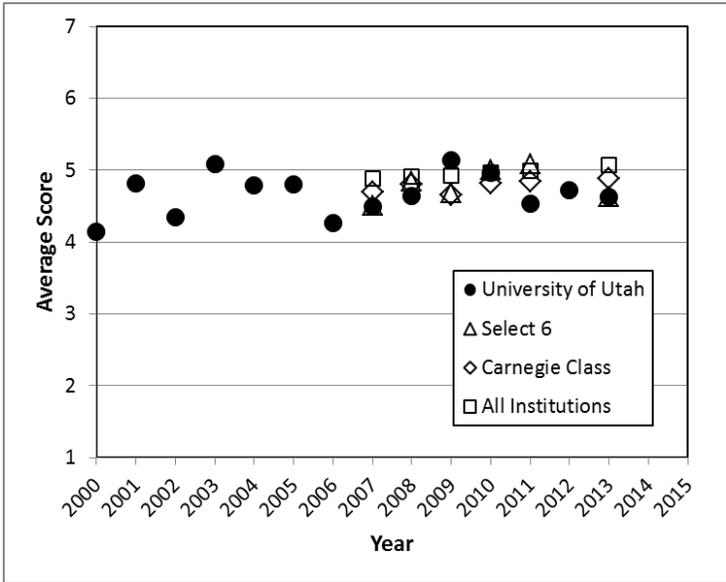


Figure 4A9-1: Response to EBI Survey Question: “I understand the impact of engineering solutions in a global context”



**Figure 4A9-2: Response to EBI Survey Question:
“To what degree did your major design experience address environmental issues?”**



**Figure 4A9-3: Response to EBI Survey Question:
“To what degree did your major design experience address sustainability issues?”**

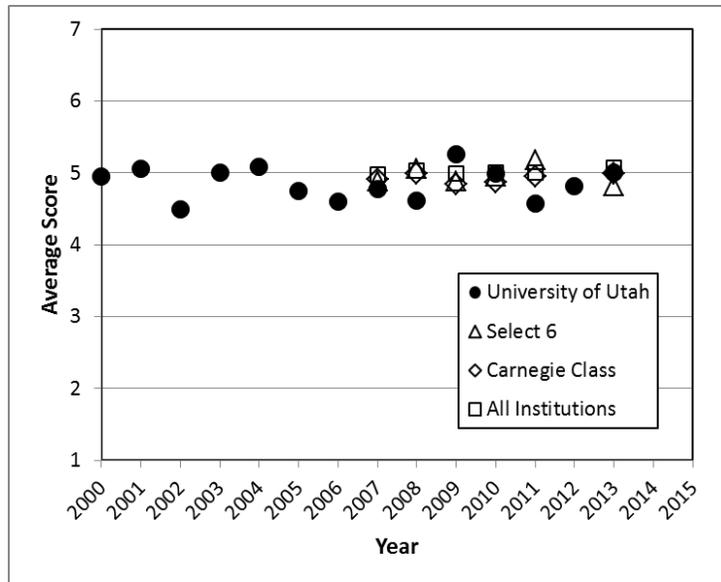


Figure 4A9-4: Response to EBI Survey Question: "To what degree did your major design experience address health and safety issues?"

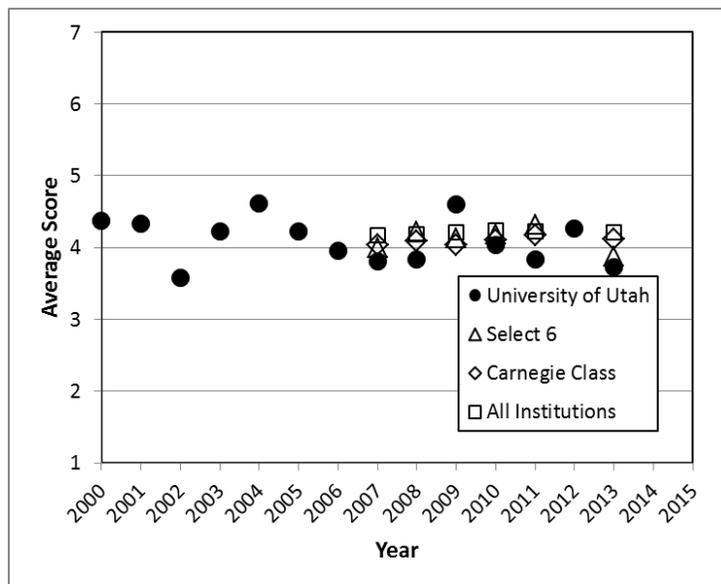


Figure 4A9-5: Response to EBI Survey Question: "To what degree did your major design experience address social issues?"

Review of Student Records for Outcome 9

General Education and Bachelor’s Degree requirements for graduation are tracked using the Degree Audit Reporting System (DARS). Because the DARS report is used to clear students for graduation, we are confident that all graduates from our program have satisfied University requirements that will enable them to understand the impact of mechanical engineering solutions in a global and societal context.

OUTCOME 10: REMAINING CURRENT (LIFELONG LEARNING)

Prior to graduation, each student in the University of Utah Mechanical Engineering Bachelor of Science Program will demonstrate an understanding of the need for, and the ability to remain current in engineering practices through lifelong learning.

Summary of Assessment:

Direct assessment of course material from the ME EN 3900 Professionalism and Ethics Seminar indicates that graduating students are receiving a high level of exposure to the need to remain current in engineering practices through lifelong learning. Our students are also very likely to be exposed to foundations and skills for (general) lifelong learning through their liberal education courses. Indirect assessment from graduating seniors via the EBI survey indicates that students are satisfied that their engineering education has enhanced their need for lifelong learning. Survey results from the departmental alumni survey suggest that our recent graduates understand the importance to remain current through lifelong learning, but perceive their ability to engage in lifelong learning as slightly lagging.

Recommended Action:

Reach out to Alumni regarding lifelong learning opportunities in an effort to increase their awareness and ability to remain current in engineering practices through lifelong learning.

Direct Assessment of Outcome 10

Review of ME EN 3900 Course Material for Outcome 10

Figure 4A-5 (above) summarizes a review of outcome coverage in the ME EN 3900 Professionalism and Ethics Seminar. Although this seminar course primarily addresses professionalism and ethics, the need for lifelong learning is a topic that is emphasized by several of the invited speakers every year. As shown in Figure 4A-5, four of the Fall 2014 seminars addressed lifelong learning to a high degree, while three seminars addressed this topic to a low degree. Thus, this 14-week seminar series continues to provide students with a high level of exposure to the need to remain current in engineering practices through lifelong learning.

General Education Council Review of Courses with General Education and Bachelor's Degree Designations for Outcome 10

While the Department of Mechanical Engineering does not keep course notebooks for liberal education courses taken by ME students, the courses with General Education and Bachelor's Degree designations are rigorously reviewed by the University's General Education Council, which makes recommendations to the Undergraduate Council. The College of Engineering has faculty representation on both of these bodies. In addition to meeting specific content criteria, the courses must also satisfy at least one of the following Personal and Social Responsibility Learning Outcomes:

- Civil engagement (local and global)
- Intercultural knowledge and competence
- Ethical reasoning
- Foundations and skills for lifelong learning

Courses with General Education and Bachelor’s Degree designations are reviewed every five years. The course syllabus as well as sample student work are provided by the home department to support the fulfillment of the content criteria and the selected Learning Outcomes. While this does not ensure that all students are exposed to “foundations and skills for lifelong learning” in their liberal education courses, it seems likely to be the case considering that students complete a minimum of 11 courses with General Education or Bachelor’s Degree designations.

Indirect Assessment of Outcome 10

EBI Survey Assessment of Outcome 10

The EBI survey of graduating seniors includes one question that is relevant to this outcome: “To what degree did your engineering education enhance your need for lifelong learning?”

The responses to this question are shown in Figure 4A10-1. Scores ranged from 1 (not at all) to 7 (extremely). The average scores from University of Utah ME students from this question are generally similar to scores from the “Select Six” institutions, the Carnegie Class schools, and for all EBI client schools. The likely explanation for the dip in 2013 is provided in Section A. University of Utah scores range from 5.2 to 5.7, indicating that students are satisfied that their engineering education has enhanced their need for lifelong learning.

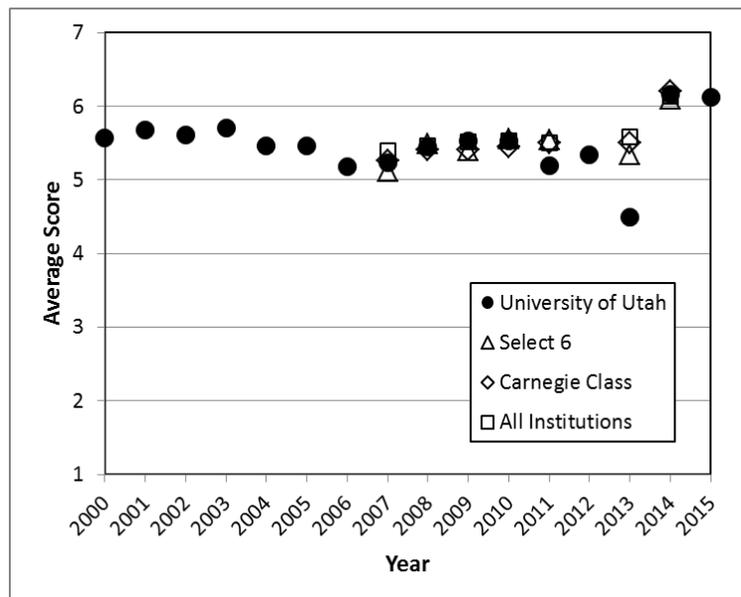
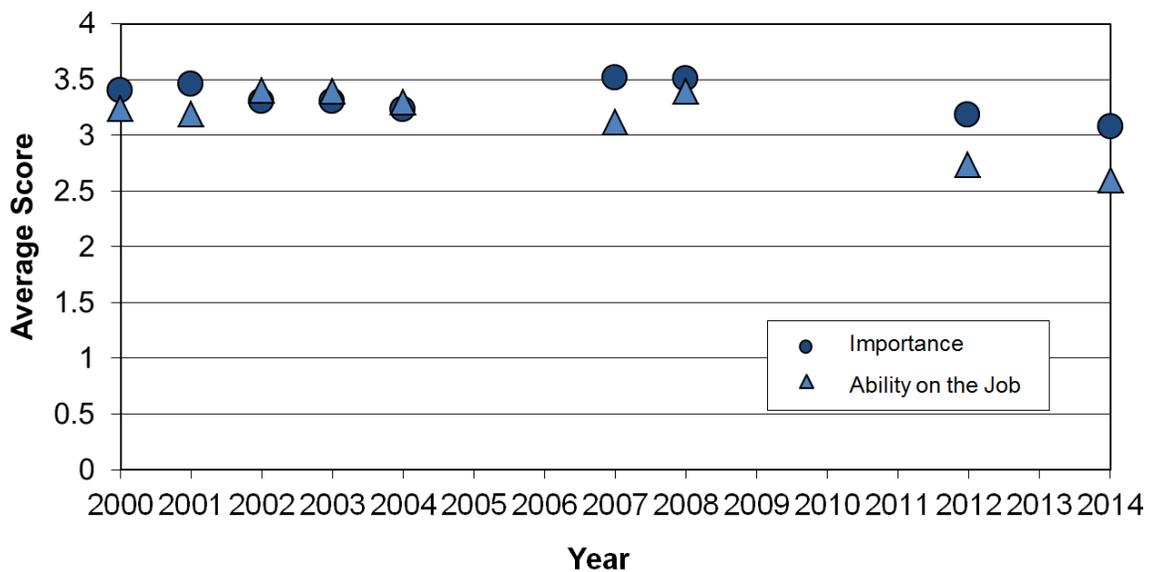


Figure 4A10-1: Response to EBI Survey Question: “To what degree did your engineering education enhance your need for lifelong learning?”

Departmental Alumni Survey Assessment of Outcome 10

In the Alumni survey, sent to students who graduated three to five years ago, a question is included that is directly related to this outcome. In this question, the alumni are asked to rate both the importance of and their ability to engage in lifelong learning. The Alumni responded using a four-step scale from 1 to 4. Figure 4A10-2 shows the results obtained from this question. In the most recent alumni surveys, there has been a decline in ratings for both importance and ability. Despite this decline, students still rate the importance of lifelong learning as important. The gap that has developed between importance and ability should be monitored during the upcoming review cycle. In the 2014 Alumni survey, 47% of graduates reported that they had taken or planned to take engineering-related workshops, and 33% indicated that they had taken or planned to take other classes. Among recent graduates of the program, 42% have attended technical conferences, 43% belong to professional societies, 31% indicate that they refer to technical journals, and 49% indicate that they engage in independent study. Additionally 18% have submitted journal articles or submitted patent applications. Together, these findings suggest that our program produces graduates who understand *and act on* the need to remain current through lifelong learning.



**Figure 4A10-2: Response to Alumni Survey Question:
“Rate the importance of and ability to engage in life-long learning”**

OUTCOME 11: CONTEMPORARY ISSUES

Prior to graduation, each student in the University of Utah Mechanical Engineering Bachelor of Science Program will demonstrate knowledge of contemporary issues impacting engineering and society.

Summary of Assessment:

Examination of the curriculum indicates that this outcome is most directly satisfied by the ME EN 3900 Professionalism and Ethics Seminar, which all Mechanical Engineering students must successfully complete. Assessment of this seminar indicates that it provides students with a modest level of exposure to “contemporary issues impacting engineering and society,” and there is a need for direct assessment of actual knowledge of contemporary issues in engineering. Results of the EBI survey of graduating seniors indicate general satisfaction that their engineering education has enhanced their ability to understand contemporary issues. Recent graduates who replied to the departmental alumni survey also indicate that they have good-to-moderate ability to understand these issues, although ratings have declined somewhat in the most recent surveys.

Recommended Action:

While this outcome is currently addressed by ME EN 3900, it is recommended that this outcome be addressed in other courses within the ME curriculum (and in a manner that has students demonstrate their knowledge of contemporary issues impacting engineering and society).

Direct Assessment of Outcome 11

Review of ME EN 3900 Course Material for Outcome 11

Figure 4A-5 (above) summarizes a review of outcome coverage in the ME EN 3900 Professionalism and Ethics Seminar. Although the main focus of this course is on professionalism and ethics, invited speakers often focus on other topics including contemporary issues impacting engineering and society. As shown in Figure 4A-5, one of the Fall 2014 seminars addressed this outcome to a high degree, while seven seminars addressed this outcome to a low degree. Thus, this 14-week seminar series continues to provide students with an exposure to “contemporary issues impacting engineering and society.”

Assessment of Student Observations of Contemporary Issues for Outcome 11

Starting a few years ago, one instructor for ME 3000 Design of Mechanical Elements shares articles from the newspaper or a magazine, or a report, and then he discusses it briefly at the beginning of the lecture in the context of the material being covered. Instructors in ME EN 1300 Statics and Strength of Materials, as well as many other required and elective courses, have done the same to varying degrees. In ME EN 3000, these articles have included articles from *The Economist* on 3D printing (and its economics), and NTSB reports on various air crashes due to

mechanical failures (that the instructor then relates to the design of mechanical elements). The students then 1) can link their knowledge to a real world example, 2) understand the magnitude of the impact mechanical design can have (people losing their lives in a plane crash), and 3) learn that engineering and economics are closely linked. This has worked quite well, to the point that a direct assessment measure has emerged: the frequency (and depth) of students choosing to locate and share articles that they find relevant to the class and would like to share with the rest of the class. One such message is quoted below. This sort of non-mandated student research also indicates an appreciation of life-long learning.

From: [REDACTED] [REDACTED]@gmail.com]

Sent: Tuesday, April 19, 2011 10:04 PM

To: [REDACTED]

Subject: Machine design article

Hello Professor [REDACTED],

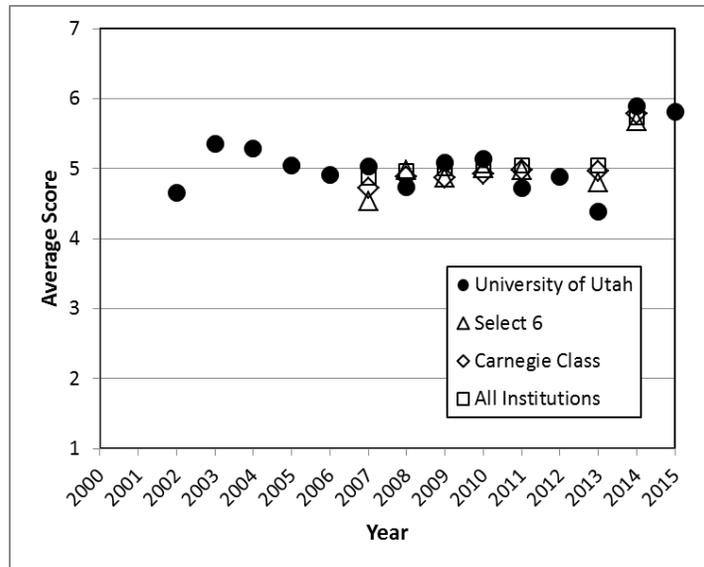
I know that this may be a little unconventional but from judging by the articles that you have passed onto our class I thought that you might find this applicable to machine design. A coworker of mine gave this article to me as he knew that I was taking a "mechatronics" class. It seems to be more Machine design though. If you find it applicable pass it onto the class but please don't reference me by name.

On another note, Thank you for being a Professor that is willing to adapt to the needs of the students. Over this semester it has become obvious that you truly care about us learning the material. I just wanted to say thank you.

Indirect Assessment of Outcome 11

EBI Survey Assessment of Outcome 11

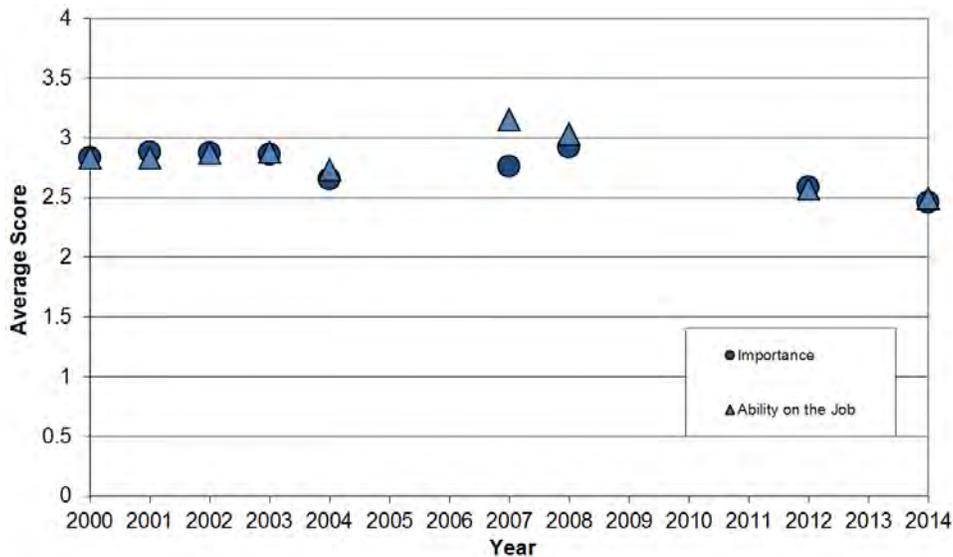
The EBI survey of graduating seniors includes one question that is relevant to this outcome: To what degree did your engineering education enhance your ability to understand contemporary issues? Revised phrasing after 2014 is in the figure caption below, where scores ranged from 1 (not at all) to 7 (extremely). Note that 2002 was the first year that this outcome was included in the survey. In the past few years (but prior to the phrasing change), Utah responses have been fairly steady around 5.0 (Figure 4A11-1). The likely explanation for the dip in 2013 is provided in Section A. These results suggest that students are generally satisfied that their engineering education has enhanced their ability to understand contemporary issues.



**Figure 4A11-1: Response to EBI Survey Question:
“I am confident that I can understand contemporary issues?”**

Departmental Alumni Survey Assessment of Outcome 11

The departmental alumni survey, sent to students who graduated three to five years ago, contains one question that is directly related to this outcome: “Rate both the importance of and your ability to know about contemporary issues.” Figure 4A11-2 shows the results obtained from this question. A 1 to 4 rating scale was used. Ratings for both the “importance” and “ability on the job” have declined during this review cycle. However, given that both scores are essentially the same, our Alumni feel that their ability to know about contemporary issues is sufficient for their career needs.



**Figure 4A11-2: Response to Alumni Survey Question:
“Rate the importance of and ability to know about contemporary issues”**

OUTCOME 12: APPLICATION OF TECHNIQUES/SKILLS OF ENGINEERING PRACTICE

Prior to graduation, each student in the University of Utah Mechanical Engineering Bachelor of Science Program will demonstrate competency in the application of techniques and skills of engineering practice.

Summary of Assessment:

Students are demonstrating competency in the application of techniques and skills of engineering practice through the requirement that they pass the Fundamentals of Engineering (FE) examination. This exam is comprehensive in nature and requires all students to solve specific problems characteristic of mechanical engineering.

Recommended Action:

No issues associated with this outcome require immediate action.

Direct Assessment of Outcome 12

Fundamentals of Engineering Examination Assessment of Outcome 12

The program's FE exam pass rate is 100%. This exam is, by definition, primarily focused on techniques and skills required for engineering practice, so this is strong evidence of meeting this outcome by the time of graduation.

OUTCOME 13: COMPETENCY IN MODERN COMPUTER-BASED TOOLS

Prior to graduation, each student in the University of Utah Mechanical Engineering Bachelor of Science Program will demonstrate competency in the application of modern computer-based tools for solving engineering problems.

Summary of Assessment:

Students consistently have scored above the national average on the computer sections of the Fundamentals of Engineering (FE) exam during the past eight years. Since the FE exam is required for graduation, this result suggests that our students continue to demonstrate competency in the application of modern computer-based tools for solving engineering problems. This conclusion is reinforced by results from the EBI survey and the departmental exit survey, both of which are taken by graduating seniors. In these indirect assessments, students indicate a "good" response to the integration of computer technology into the curriculum and appear satisfied by their ability to use computational tools. Three courses with significant use of computer tools (ME EN 1000 Introduction to Mechanical Design for Engineering Systems, ME EN 1010 Computer-Based Problem Solving for Engineering Systems,

and ME EN 2450 Numerical Methods for Engineering Systems) have undergone recent changes resulting from the review of the first two year’s curriculum (2013). Continued monitoring of this outcome is warranted based on these recent changes.

Recommended Action:

No immediate action is necessary for this outcome, but continued monitoring is warranted based on mid-cycle (2013) changes to freshman- and sophomore-level courses with significant use of computer tools.

Direct Assessment of Outcome 13

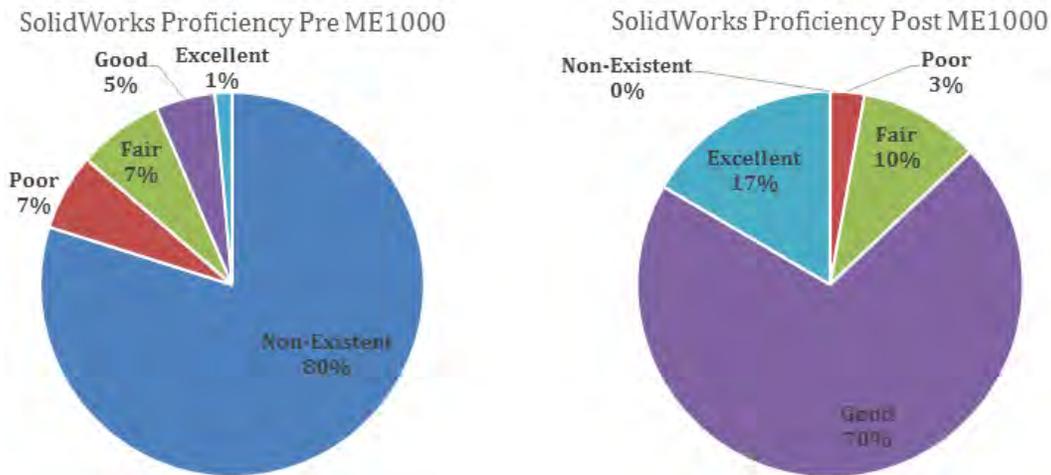
Fundamentals of Engineering Examination assessment of Outcome 13

The program’s FE exam pass rate is 100%. This exam’s coverage of modern computer-based tools provides additional evidence of meeting this outcome by the time of graduation.

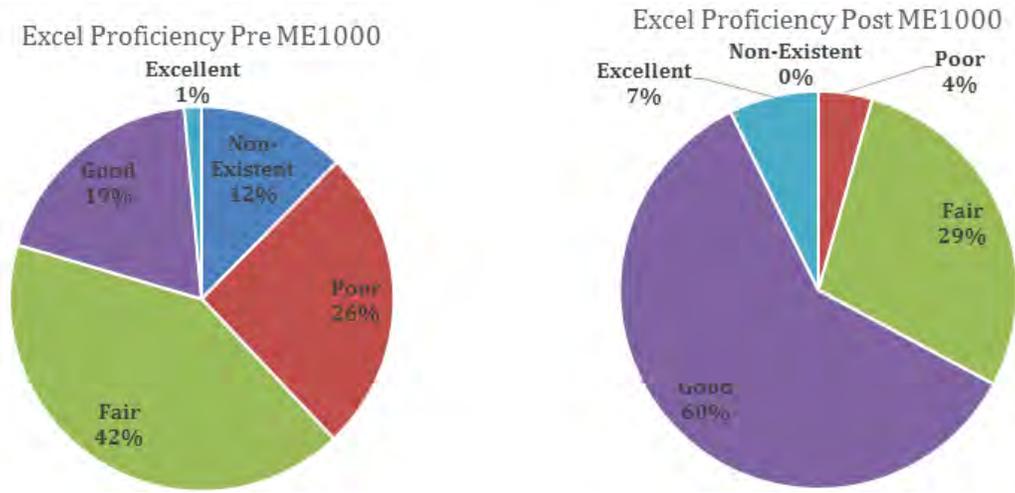
Indirect Assessment of Outcome 13

ME EN 1000 Student Survey Assessment of Outcome 13

All students in the ME undergraduate program are required to take ME 1000 Introduction to Mechanical Design for Engineering Systems, or equivalent. In this class, students are introduced to software tools for problem solving. SolidWorks is used as a visualization and creation tool. Students brainstorm ideas to solve challenging open-ended problems and draft their ideas using SolidWorks. Additional analyses and data visualization skills are taught using Microsoft Excel. A competency survey is given at the beginning and end of the course to assess how students rate their abilities to use these software tools. The overwhelming majority of students reported no proficiency prior to the class, and nearly all rated their proficiency as “Good” to “Excellent” upon completing the course as shown in Figures 4A13-1a and 4A13-1b.



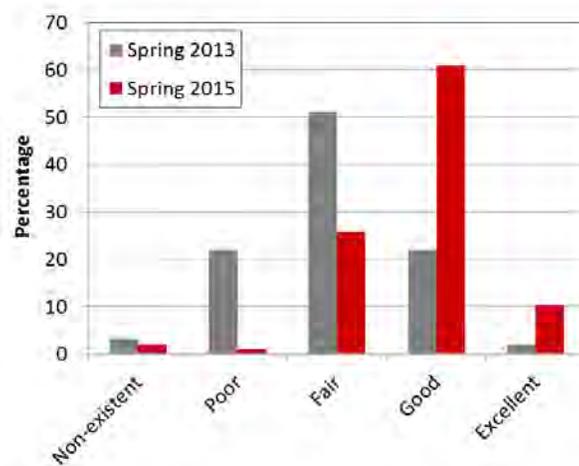
**Figure 4A13-1a: Response to ME EN 1000 Survey Questions:
“Rate your ability to use Solidworks/Excel”**



**Figure 4A13-1b: Response to ME EN 1000 Survey Questions:
“Rate your ability to use Solidworks/Excel”**

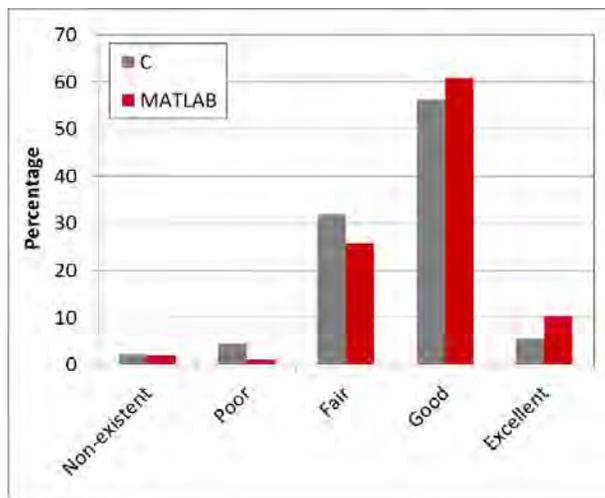
ME EN 1010 Student Survey Assessment of Outcome 13

ME EN 1010 Computer-Based Problem Solving for Engineering Systems provides instruction in programming in both MATLAB (approximately 4/5 of the lectures) and C (remaining 1/5 of the lectures). In an end-of-course survey, students are asked to rate their programming proficiency before and after taking the course. Figure 4A13-2 shows data from 96 students (79% of survey respondents) from Spring 2013 (SPIRAL ME EN 1010) and 97 students (89% of survey respondents) from Spring 2015 who indicated that their MATLAB programming proficiency *before* taking ME EN 1010 was non-existent. As seen from the graph, the revisions to ME EN 1010 (effective Spring 2014) resulted in a shift towards higher reported MATLAB proficiencies at the end of the semester, with an average increase of 2.8 points for Spring 2015 compared to only 2 points for Spring 2013 (where 4 is the maximum possible increase in rating points). These results indicate that the changes made to ME EN 1010 in Spring 2014 have been effective in improving students’ programming skills.



**Figure 4A13-2: Response to ME EN 1010 Survey Question:
“After taking this class, my MATLAB proficiency is ...”**

Figure 4A13-3 shows the same MATLAB data for Spring 2015 as well as the same question for C programming for Spring 2015. The C data corresponds to 91 students (83% of survey respondents) who reported that their C programming proficiency was non-existent *before* taking ME EN 1010. The average reported increase in C programming proficiency is slightly lower than that for MATLAB (2.6 compared to 2.8), but this is not surprising since more lecture time is devoted to MATLAB programming. Overall, 97% of all Spring 2015 survey respondents reported at least “Fair” MATLAB competency, with 73% reporting “Good” or “Excellent” competency. For C, 94% of all Spring 2015 survey respondents reported at least “Fair” competency, with 62% reporting “Good” or “Excellent” competency. These are viewed as satisfactory results for the introductory programming course. Students continue to improve their MATLAB skills in ME EN 2450 Numerical Methods for Engineering Systems, and their Arduino C skills in ME EN 3200/3210 Mechatronics I/II.



**Figure 4A13-3: Response to ME EN 1010 Survey Questions:
“After taking this class, my C/MATLAB proficiency is ...”**

EBI Survey Assessment of Outcome 13

The EBI survey for graduating seniors includes one question that is directly related to this outcome: “To what degree did your engineering education enhance your ability to use modern engineering tools?” The responses to this question are shown in Figure 4A13-4 below (with the caption showing the rephrasing of this question as of 2014). Scores ranged from 1 (not at all) to 7 (extremely). The average responses from University of Utah ME students from these questions are comparable to those for the “Select Six” institutions, the Carnegie Class schools, and for all EBI client schools. University of Utah scores in the most recent years (prior to the rephrasing) typically fall between 5.0 and 5.5. The likely explanation for the dip in 2013 is provided in Section A. These results suggest that overall, students remain satisfied by their ability to use computational tools.

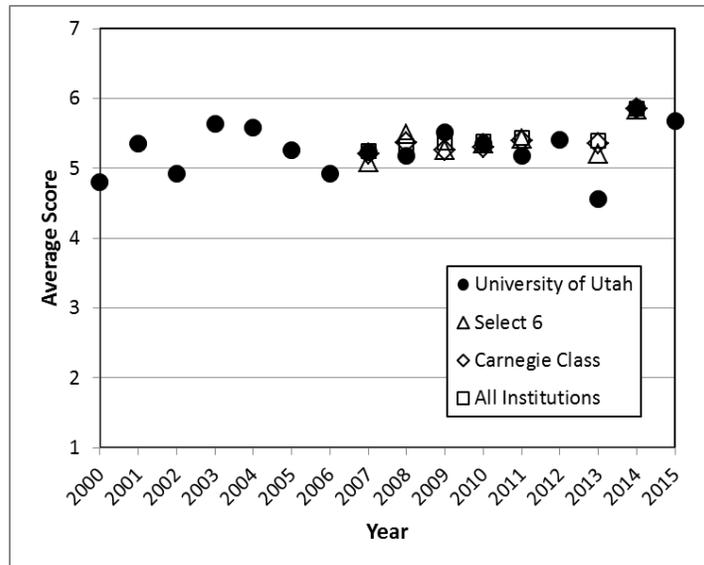


Figure 4A13-4: Response to EBI Survey Question: “I am confident that I can use modern engineering tools”

Departmental Exit Survey Assessment of Outcome 13

One question on the ME departmental exit interview survey relates to this outcome: “Rate the computer technology integration into courses.” Figure 4A13-5 shows the results obtained from this question. Scores have been at or above 3.0 for the past several years. Overall, these results suggest a “good” response for the integration of computer technology into courses.

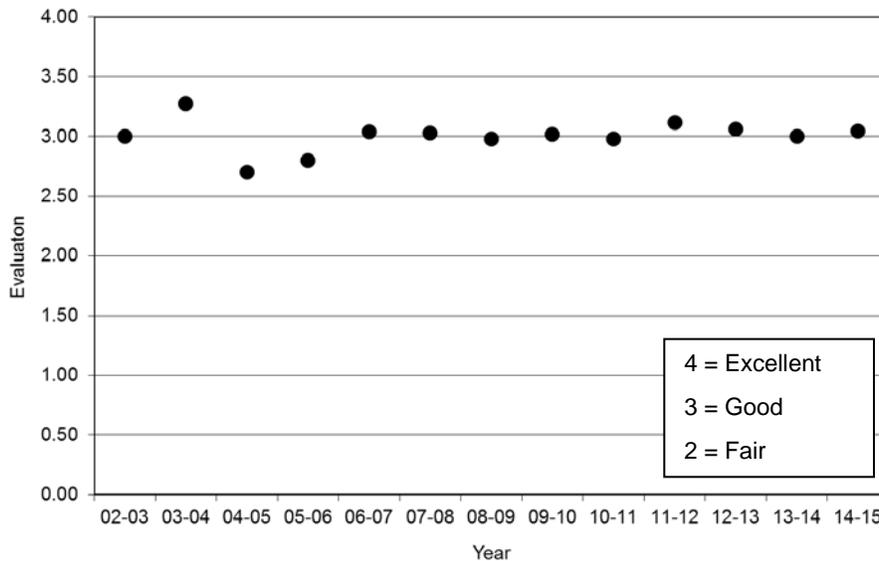


Figure 4A13-5: Response to Exit Survey Question: “Rate the computer technology integration into courses”

OUTCOME 14: PARTICIPATION IN CAPSTONE DESIGN

Prior to graduation, each student in the University of Utah Mechanical Engineering Bachelor of Science Program will demonstrate participation in a capstone design project and optional participation in faculty-led research, cooperative internships, design projects, and independent study projects.

Summary of Assessment:

Assessment data indicates that all students are graduating with a Capstone Design experience (this is a requirement for graduation). Thus, this outcome is being achieved by all students. Additionally, a large number of students are participating in optional project-based experiences. For example, a total of 66 undergraduate students (approximately eight percent of the undergraduate student body) participated in faculty-led research during the 2014-2015 academic year. Graduation data shows that over the past eight academic years, approximately six percent of graduates received credit for independent study with a faculty member (most often for undergraduate research) via ME EN 5950 Independent Studies in Mechanical Engineering. Occasionally, undergraduate research has led to peer-reviewed full journal articles. In addition, approximately seven percent of graduates received credit for work on design projects via ME EN 5920 Design Project, and approximately 12% of graduates enrolled in ME EN 5910 Cooperative Education to receive credit for cooperative internship experiences.

Recommended Action:

No issues associated with this outcome require immediate action.

Direct Assessment of Outcome 14

Review of Student Records for Outcome 14

All students participate in the Capstone Design sequence (i.e., ME EN 3000 Design of Mechanical Elements, and ME EN 4000/4010 Engineering Design I/II) as a requirement for graduation. Thus, prior to graduation, all students have demonstrated participation in a capstone design project.

Students enroll in ME EN 5910 Cooperative Education to receive credit for a cooperative internship experience. Figure 4A14-1 shows the number of graduates who have participated in ME EN 5910 each year since 2008. The average number of graduates with ME EN 5910 credit is 15 per academic year, or approximately 12% of all graduates. There are currently 21 students enrolled in ME EN 5910 for Summer 2015.

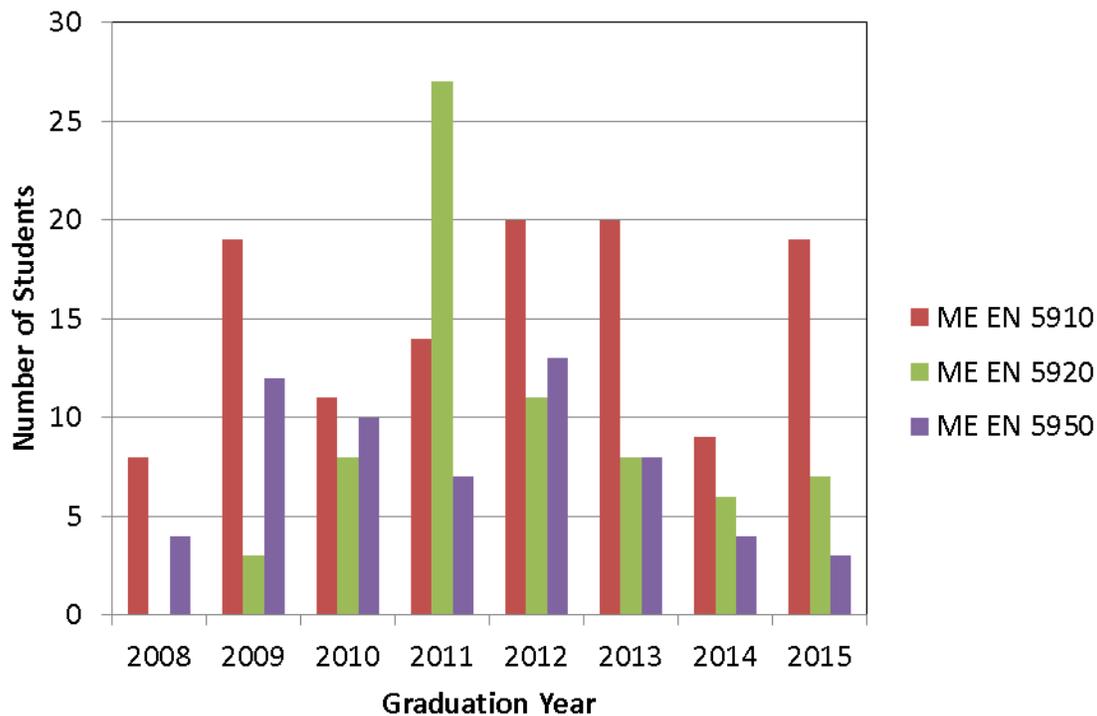


Figure 4A14-1: Enrollment in ME EN 5910 Cooperative Education, ME EN 5920 Design Project, and ME EN 5950 Independent Study

Students enroll in ME EN 5920 Design Project to participate in an independent design project. Figure 4A14-1 shows the number of graduates who have participated in ME EN 5920 each year since 2008. The average number of graduates with ME EN 5920 credit is nine per academic year, or approximately seven percent of all graduates. The most common Design Project experience is associated with Formula SAE, including most of the 27 2011 graduates with ME EN 5920 credit. There are currently 10 students enrolled in ME EN 5920 for Summer 2015, all working on the Formula SAE project.

Students enroll in ME EN 5950 Independent Study to study a subject not covered in existing courses or to participate in undergraduate research. Figure 4A14-1 shows the number of graduates who have participated in ME EN 5950 each year since 2008. The average number of graduates with ME EN 5950 credit is eight per academic year, or approximately six percent of all graduates.

Faculty Undergraduate Research Survey Assessment of Outcome 14

Once per ABET review cycle, all Mechanical Engineering faculty members are asked to respond to a short survey containing two questions:

1. How many undergraduate students were you involved with in “faculty-led research” during the past academic year?
2. What was your overall impression of working with undergraduate students in “faculty-led research during the past academic year? Choose one:

- 5 Highly favorable
- 4 Favorable
- 3 Neutral
- 2 Unfavorable
- 1 Highly unfavorable

A total of 20 faculty members responded that they had been involved with faculty-led research with undergraduates during the academic year. They reported 66 undergraduate students in their labs, which by comparison is equal in size to approximately 44% of the 2015 graduating class (although not all of the participating students are seniors). All 20 faculty members reported that their overall impression was either neutral (6 response), favorable (7 responses) or highly favorable (6 responses).

Select faculty comments:

- *“These students have made important contributions to research in our lab and have both now indicated interest in going on to graduate school.”*
- *“I find that we have some highly motivated and intelligent undergraduates. I have one publication with an undergraduate and expect to have one more this year.”*
- *“URA’s continue to be important to me in my research program. They have also been a good source of follow-on graduate students.”*
- *“I published an international journal article with a sophomore student who generated failure probability isosurfaces in MATLAB via 40-thousand Mohr’s circles!”*
- *“Some students are great. Others are not very good.”*

OUTCOME 15: ABILITY TO WORK IN THERMAL OR MECHANICAL SYSTEMS

Prior to graduation, each student in the University of Utah Mechanical Engineering Bachelor of Science Program will demonstrate an ability to work professionally in thermal or mechanical systems, with knowledge of each area.

Summary of Assessment:

This is a new student outcome that received final (unanimous) approval by the program's industrial advisors in May of 2015. To date, review teams for each required course in the curriculum have been solicited to indicate the degree to which their course contributes to achievement of this outcome, to recommend formalized assessment strategies, and to comment on degree of attainment evident in student work or concerns/praise in student exit surveys.

Recommended Action:

As this is a new outcome (and thus not strictly subject to analysis during this ABET review cycle), all courses that have been associated with attainment of this outcome are to slated to have their end-of-course surveys modified to solicit student feedback pertaining to Outcome 15. Focused attention on establishing assessment tools and timeline for this outcome is anticipated for the next summer Faculty Retreat meeting. Nevertheless, as this outcome is essentially the same as Criterion 9, achievement is summarized in that section rather than here.

COMPARATIVE OUTCOME ASSESSMENT

Summary of Assessment:

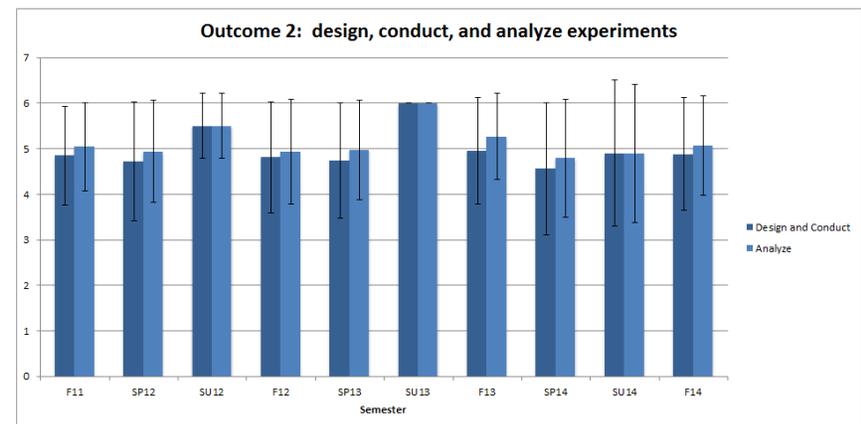
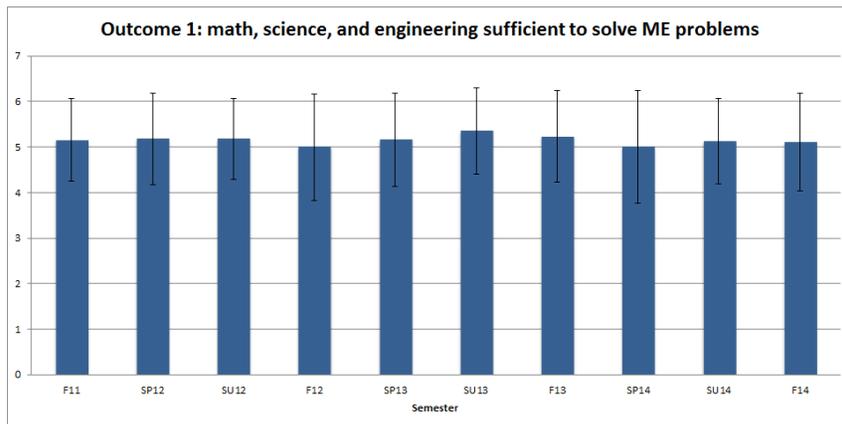
Whereas the preceding sections provided data for each outcome individually as separate discussions, this section covers all outcomes at once to show a more holistic view of the program's effectiveness.

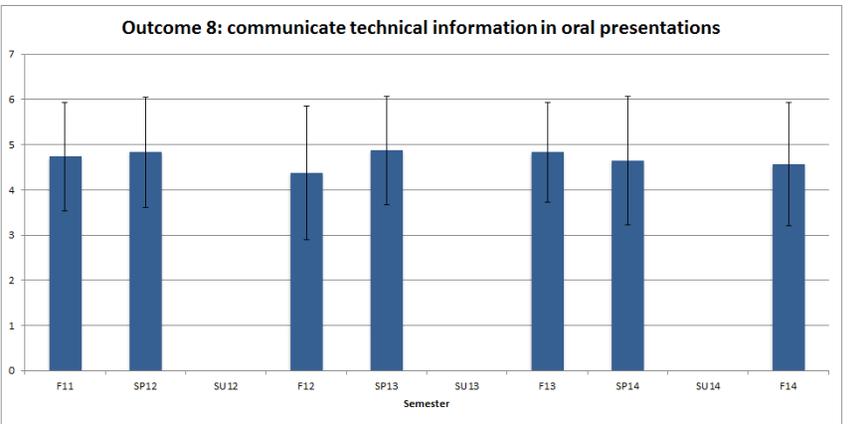
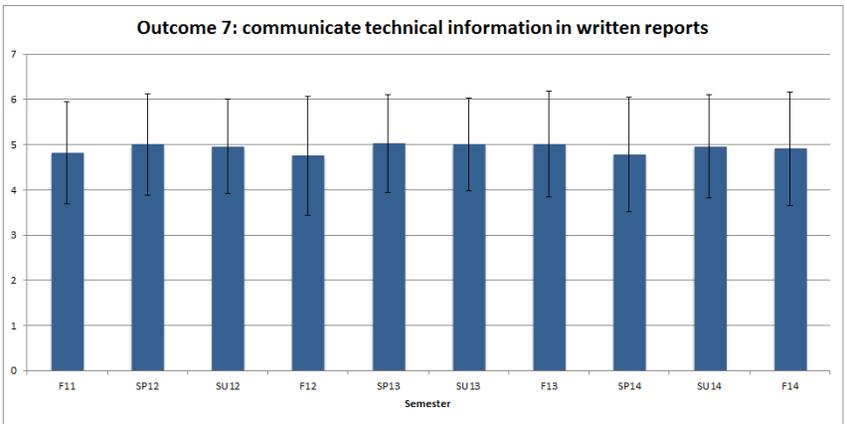
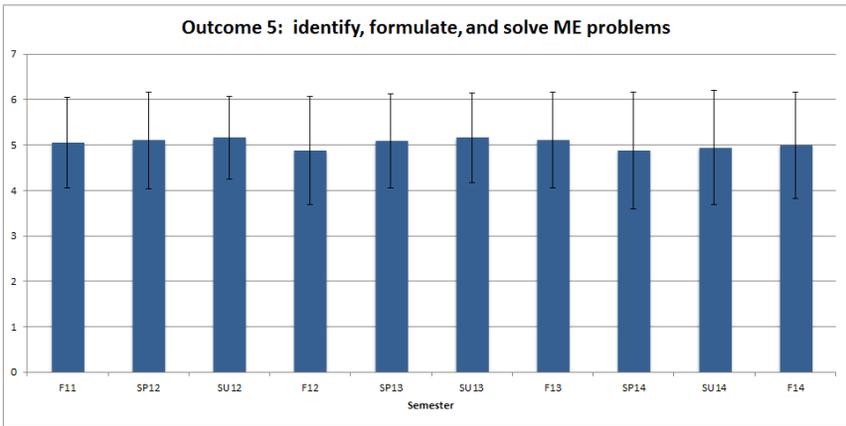
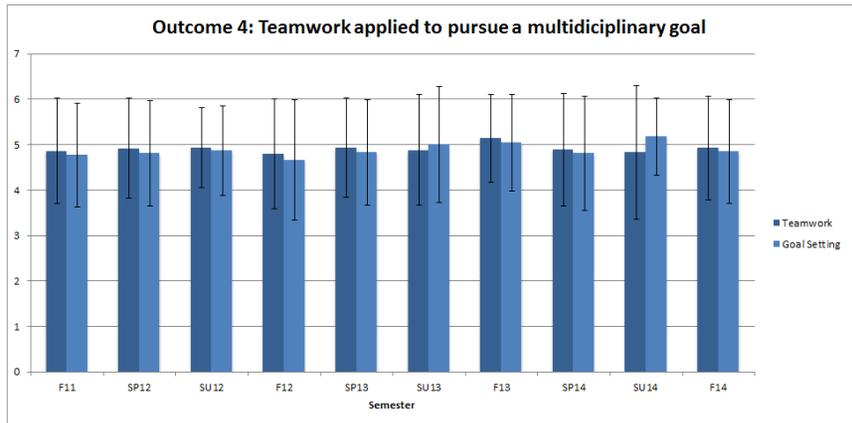
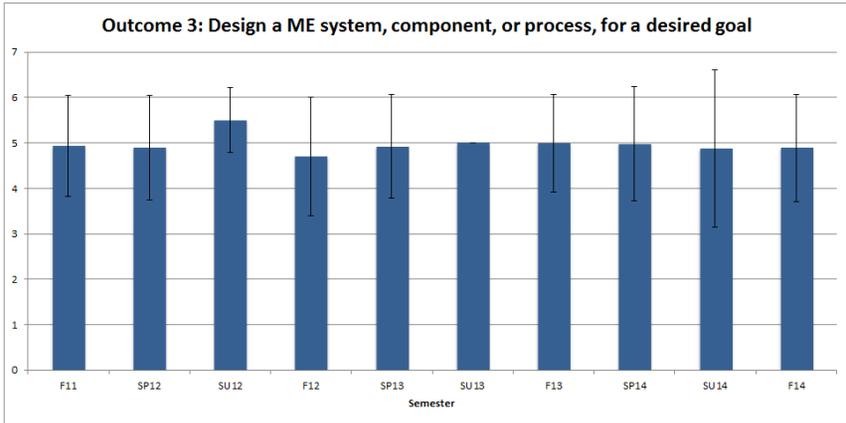
Recommended action:

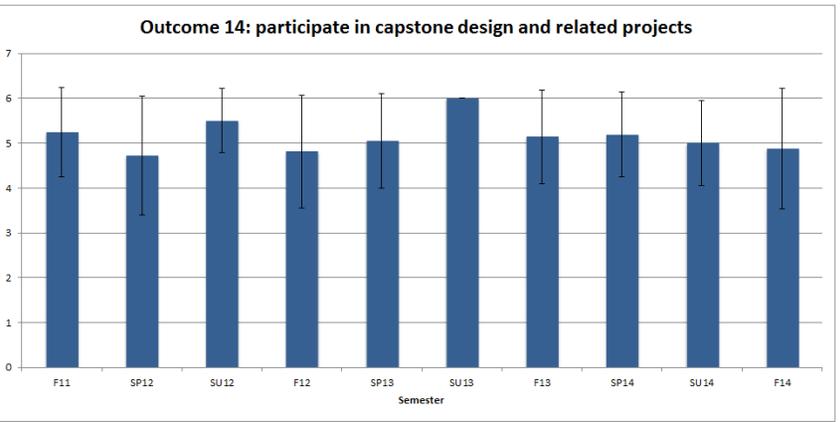
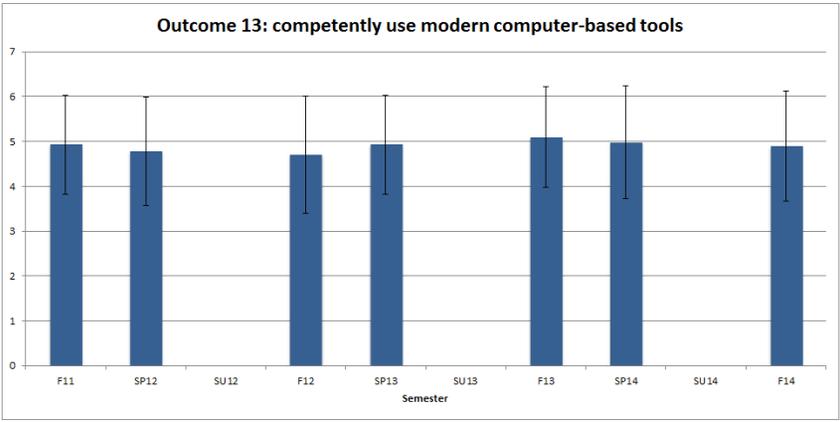
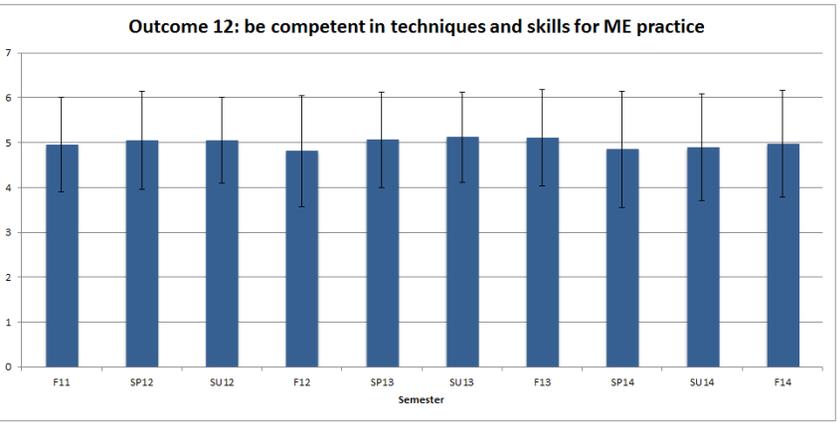
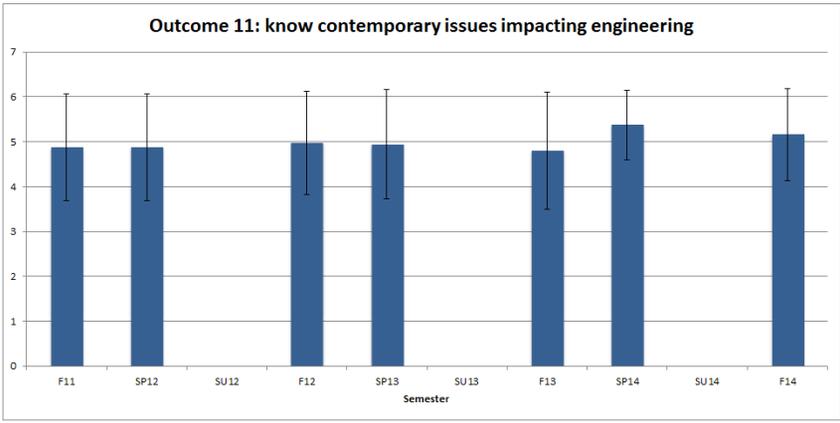
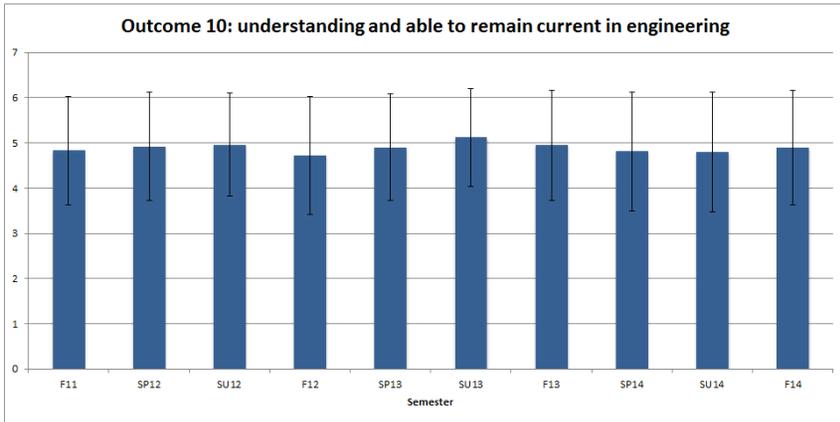
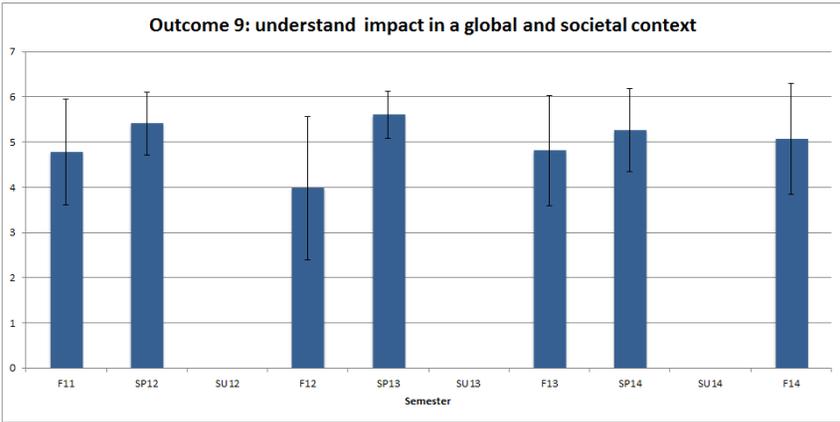
In student course feedback, scores generally hover around 5 (thus meeting outcome achievement goals), but existence of larger error bars (as in outcome 4: teamwork) suggest polarization of opinions, which should trigger scrutiny of what precisely is causing difficulties among the students who give very low ratings. High ratings with small error bars, on the other hand, require no investigative actions.

Summary of supporting data from course evaluations:

The average student satisfaction for all outcomes is around 5 (agree), which is well above our "corrective action" trigger value of 4.5 (half-way between "agree" and "mildly agree"). The isolated exceptions were followed immediately with improved scores above the trigger value.







Documentation

All assessment records are archived in a College-maintained dedicated file system that is available to the evaluator during the accreditation visit (or sooner via VPN login). ABET course notebooks are solicited for all of the courses listed in Table 5-1 every time the course is offered. These course notebooks contain copies of the syllabus, homework assignments, quizzes and exams, and examples of student work. These course notebooks, which are reviewed as needed during the outcome assessment cycle, will be available for review by the evaluation team. Each review cycle, faculty teams are instructed to review accuracy of Table 5-1 to ensure that the curriculum continues to include adequate coverage of all Student Outcomes in specific courses. Those reviews are available to the evaluator, along with course notebooks. Additionally, a detailed ABET outcome assessment conducted by the curriculum committee during Fall 2013 is available.

B. Continuous Improvement (Actions to improve the Program)

This section describes how the results of evaluation processes for the student outcomes and any other available information have been systematically used as input in the continuous improvement of the program. Results of all changes (whether or not effective) are provided in those cases where re-assessment of the results has been completed. Significant future program improvement plans based upon recent evaluations are discussed, with a brief rationale for each of these planned changes.

This section is organized as a collection of the significant actions that have been taken during this review cycle to improve the Mechanical Engineering program at the University of Utah. The actions are listed chronologically, starting from our last ABET accreditation visit in 2009.

ACTION 1. Redevelop four core courses in the ME lower division curriculum

Date: Implemented Fall 2009

Basis for Action: Direct assessment of students' competence in computational skills following their freshman and sophomore years showed that they had not retained an acceptable level of proficiency required for the computational tasks planned in the core ME junior level courses. This deficiency was believed to be due to a lack of continued usage of the computational tools following the initial teaching. In addition, there was a desire to: 1) address the well-publicized challenges of educating the current generation of American students with their short attention spans, expectations of immediate rewards, and limited "hands-on" experience (vs. years of "fingers-on" experience with modern electronic devices), 2) improve our graduates' professional skills as recommended by practicing engineers, and 3) implement improved pedagogical techniques via an overriding "design as knowledge" teaching philosophy that teaches through an emphasis on model-based design and product realization.

Results: A NSF CCLI proposal, developed and submitted by ME faculty (R. Roemer, PI) to address this issue, was funded in 2009. Through this NSF grant, four core ME courses at the freshman and sophomore levels (ME EN 1000, CS 1000, ME EN 2450, and ME EN 2300 – see Table 4B1-1) were redeveloped into an integrated sequence based on a design-motivated, Student-driven Pedagogy of Integrated, Reinforced, Active Learning (SPIRAL) approach. With

this approach, the teaching of basic engineering knowledge and skills was distributed through multiple courses in order to enhance student understanding through repetitive exposure at ever-increasing depths. As such, each new course (ME EN 1000, 1010, 2500, and 2510 – see Table 4B1-1) was designed to teach specific engineering science topics in addition to design practice and methodology, computer-aided engineering skills, and professional engineering skills, with an open-ended, collaborative learning-based design project utilized as a vehicle to motivate and teach the material. The first year courses (1000 and 1010) focused on design methodology and computer programming, with an overarching theme of robotic/mechatronic systems. The second-year courses replaced traditional stand-alone courses in Numerical Methods and Thermodynamics, and emphasized sustainability in engineering. The robotics/mechatronics and sustainability themes were chosen as broad contemporary topics that would attract students to and retain students in the program.

Table 4B1-1: SPIRAL revisions to four core courses

Previous Course	Cr. Hr.	SPIRAL Course	Cr. Hr.
ME EN 1000 Design and Visualization	3	ME EN 1000 Introduction to the Design of Robotic Systems I: Mechanical Systems	3
CS 1000 Engineering Computing	3	ME EN 1010 Introduction to the Design of Robotic Systems I: Sensors and Actuators	3
ME EN 2450 Numerical Techniques in Engineering	2	ME EN 2500 Introduction to the Design of Sustainable Energy Systems: Wind and Water Power	3
ME EN 2300 Thermodynamics I	2	ME EN 2510 Introduction to the Design of Sustainable Energy Systems: Thermal and Solar Power	3

First-year sequence

ME EN 1000: This course focused on design methodology, and was organized into the following modules: Engineering Design, Engineering Mechanisms (e.g., springs and pulleys), Engineering Modeling (Newtonian and energy methods), and Engineering Professionalism (e.g., economics and safety). Engineering design content was complemented by CAD instruction in lab, while the modeling was supported by Excel instruction.

ME EN 1010: The focus of this class was computer programming (half of the lectures), with the remaining lectures covering a variety of engineering topics including circuits, sensors, electromechanical actuators, linkages, economics, safety, ethics, and communication/teamwork. Programming lectures and lab/homework assignments were aligned with the engineering/project topics. The primary programming language was MATLAB, with a brief introduction to C to allow students to program Arduino microcontrollers for the project.

Design Projects: Semester-long, team-based design projects were developed for both ME EN 1000 and 1010. The ME EN 1000 project involved the design and construction of a

mechanically-powered autonomous vehicle (e.g., that could drive as far as possible and launch a projectile as far as possible using a set amount of potential energy). For the ME EN 1010 project, students designed and constructed an electro-mechanically actuated vehicle (e.g., that could navigate a course and shoot at targets).

Labs: New hands-on laboratories were implemented to support the design projects in both ME EN 1000 and 1010. The general format of the laboratory meetings was a one-hour software tutorial (Excel in 1000 and MATLAB in 1010) followed by a two-hour lesson on either software or hardware. In ME EN 1000, the two-hour lessons covered hand drawing, computer-aided design using SolidWorks, engineering topics including springs, pulleys, gears, friction and traction, manufacturing topics including safety, hand tools, and waterjet cutting, and communication instruction. In ME EN 1010, the two-hour lessons included an introduction to electronics and programming using the Arduino microcontroller platform, mechanical and electromechanical hardware topics including fourbar linkages, motors, solenoids and sensors, and advanced SolidWorks and communication instruction.

Second-year sequence

ME EN 2500: This course focused on Numerical Methods, building directly on the programming experience obtained during the previous semester in ME EN 1010. The sustainable energy theme of wind and water power introduced the students to fluid dynamics through fluids-based examples in lecture and homework assignments.

ME EN 2510: The main engineering science topic of this course was Thermodynamics. Here, thermal power sources were emphasized as sustainable energy solutions and highlighted in lecture and laboratory experiences.

Design Project: A year-long, team-based design project was designed around the sustainable energy theme. Students designed an air-powered train to compete in a race involving a straight track, two tunnels, mail pickup and drop off, and removing a cow from the tracks. The project “SPIRALed” the design methodology, communication, teamwork, programming, manufacturing and hardware skills acquired during ME EN 1000 and 1010. For example, students were introduced to new manufacturing tools and techniques as well as new sensing and actuation techniques. They continued to use Arduino microcontrollers, and were exposed to advanced SolidWorks techniques such as flow modeling and finite element analysis.

Labs: Newly developed labs for the sophomore course sequence included four components, all of which closely supported the design project: Arduino, numerical methods, machine shop, and CAD. Each ME EN 2500 lab included both a numerical methods tutorial and a hands-on Arduino-based lab experience (e.g., analog-to-digital conversion) or a CAD experience (e.g., flow simulations in SolidWorks). In the ME EN 2510 labs, students learned to operate manual mills and lathes and performed Thermodynamics-related Arduino labs involving temperature and pressure measurements.

Note on manufacturing: While it was intended that the ME EN 2650 Manufacturing Lab (1 credit) would be completely integrated into the SPIRAL sequence, this turned out to be impractical. After teaching manual mill and lathe labs during the first offering of ME EN 2510 (Spring 2011), a new separate lab course (ME EN 2660 Machining Lab, 0.5 credits) was introduced in Fall 2011 for manual mill and lathe instruction. Students continued to be introduced to shop safety, metrology, hand tools, water jet cutting, 3D printing, and CNC tools during the SPIRAL courses.

The four-course SPIRAL sequence was taught for 4 years (2009-10 to 2012-13 academic years). The SPIRAL curriculum received national recognition from several channels for its innovation and contributions to engineering education. Three papers submitted to the 2010 and 2011 ASEE Annual Conferences won two Best Paper Awards and one Honorable Mention. We were one of 28 engineering programs recognized in the National Academy of Engineering's "Infusing Real World Experiences into Engineering Education" publication (November 2012). Our group was also invited to present our work at the 2013 ASME International Mechanical Engineering Education Leadership Summit on a panel including other top programs (Ohio State University, University of Illinois at Urbana-Champaign, University of Michigan, Stanford University and others). Internally, a full review of the SPIRAL curriculum was conducted in 2013, which resulted in the changes presented in ACTION 5)

ACTION 2. Integrate instruction on oral presentations with attention to audience, purpose, and context

Date: Implemented in 2009 (as part of SPIRAL) and monitored in subsequent years.

Basis for Action: SPIRAL NSF grant cited data suggestive that integration of instruction on oral presentations produces better learning outcomes.

Results: The CLEAR Program Director worked with the engineering faculty to restructure a variety of presentation assignments to be integrated into two required freshman (ME EN 1000/1010 Introduction to the Design of Robotic Systems I/II) and two required sophomore (ME EN 2500/2510 Introduction to the Design of Sustainable Energy Systems I/II) classes. Each assignment required students to adapt a presentation to a particular audience and to prepare the presentation according to the purpose and context of the assignment. Students delivered the presentations in lab and they received feedback from the oral communication consultant.

ACTION 3. Integrate instruction on writing with attention to genre considerations, audience, purpose, and context

Date: Implemented in 2009 (as part of SPIRAL) and monitored in subsequent years

Basis for Action: Spiral NSF grant cited data suggestive that integration of instruction on technical writing produces better learning outcomes. Additionally, general faculty direct assessments of written student work found that communication could be improved.

Results: The CLEAR Program Director worked with the engineering faculty to restructure a variety of written assignments to be integrated into two required freshman (ME EN 1000/1010 Introduction to the Design of Robotic Systems I/II) and two required sophomore classes (ME EN 2500/2510 Introduction to the Design of Sustainable Energy Systems I/II). Each assignment required students to conform to a specified genre, adapt to a particular audience, and select

content according to the purpose and context of the assignment. Students wrote memos and reports, and received feedback from the written communication consultant, often with opportunities for revision.

ACTION 4. Eliminate ME EN 4050 Concurrent Engineering II

Date: Decision in Fall 2009 (as part of SPIRAL revisions), last course offering in Spring 2013

Basis for Action: This course was initially added to the curriculum when the department had a faculty member (now retired) with significant interest in reliability, fatigue, failure, wear, corrosion, and tribology. During the reorganization of program content with the implementation of the SPIRAL curriculum, some material in ME EN 4050 was deemed to be more appropriate for (and was in fact already being covered in) technical elective courses. In addition, ME EN 4050 included significant coverage of statistics, but this was found to be redundant with the statistics coverage in ME EN 3000 Design of Mechanical Elements (added to this course during the previous ABET review cycle based on student feedback that statistics topics were presented too late in the program).

Results: ME EN 4050 was eliminated as a required course in the SPIRAL curriculum. Much of the content was being covered in technical electives such as ME EN 5030 Reliability Engineering and ME EN 5040 Quality Assurance Engineering, while the statistics content had already been moved to ME EN 3000, as discussed above. Because ME EN 4050 remained a graduation requirement for students in the pre-SPIRAL curriculum, the course was offered through Spring 2013.

ACTION 5. Review Freshman and Sophomore SPIRAL Curriculum

Date: Summer 2013

Basis for Action: Leading up to Fall 2009, the Mechanical Engineering Department undertook a major modification of much of its freshman and sophomore curriculum. Termed the SPIRAL curriculum (Student-driven Pedagogy of Integrated, Reinforced, Active Learning), the objective was to integrate material from multiple topics and provide more reinforcement of topics throughout a student's undergraduate career with significant hands-on, active learning. This program was set up with the goal of increasing retention, attracting more students from traditionally under-represented groups, and providing a more relevant engineering education by stressing the integration of material across the curriculum. The resulting revision/development of four new courses was discussed in detail in Action 1 above.

Unfortunately, student response to the classes as well as instructor feedback indicated that both students and faculty members were struggling with the new curriculum. These struggles remained four years after starting the new SPIRAL program. It was not clear if this was a problem with the way material was presented, the amount of material presented, inherent student resistance to new ideas and teaching pedagogies, or a fundamental problem with the make-up of the curriculum. To formally address this, the department chair established a SPIRAL Review Committee in 2013 to review the curriculum and make recommendations.

In conducting the review, the committee undertook the following process:

- Educate themselves on pre-SPIRAL and SPIRAL Curriculum
- Review all information available (see next paragraph)
- Assess strengths/weaknesses
- Ensure specific learning objectives and outcomes are explicitly articulated
- Develop preliminary recommendations
- Evaluate recommendations in terms of quality and constraints of the program
- Iterate on recommendations

The information used in the review included

- Student teaching evaluations (pre-SPIRAL and SPIRAL)
- Syllabi
- Course surveys
- ASEE Papers
- Senior exit surveys
- Interviews with faculty members involved in SPIRAL
- Performance and retention data
- Input from Strategic Planning Committee
- Anecdotal student and faculty perceptions
- Feedback on preliminary recommendations
- Comparison with other universities

Results: The outcome of the evaluation was a set of general recommendations that were implemented as specific modifications as appropriate to each individual course. The general recommendations included:

- Change course title to reflect core competency
- Remove much of the “other” content (e.g., safety, ethics, manufacturing, advanced topics not yet covered in core classes)
- More focus on the core competency of each class (i.e., design, programming, numerical methods, thermodynamics)
- Maintain hands-on and teamwork experiences where possible, while streamlining design assignments to reduce overall workload and make them more relevant to the core competency of the course
- Make courses more modular to respect our articulation agreements

While significant issues with the program were apparent, the review also indicated important strengths of the SPIRAL program that were retained in the course changes. These included hands-on work, online content, and comprehensive design projects.

Starting Fall 2013, the recommendations were implemented in the four freshman/sophomore SPIRAL classes Table 4B5-1 shows an overview of the changes:

Table 4B5-1: Post-SPIRAL revisions to four core courses.

SPIRAL Course	Cr	Lab	Proj	Post-SPIRAL Course	Cr	Lab	Proj
ME EN 1000 Introduction to the Design of Robotic Systems I: Mechanical Systems	3	X	X	ME EN 1000 Introduction to Mechanical Design for Engineering Systems	3	X	X
ME EN 1010 Introduction to the Design of Robotic Systems I: Sensors and Actuators	3	X	X	ME EN 1010 Computer-Based Problem Solving for Engineering Systems	3	X	X
ME EN 2500 Introduction to the Design of Sustainable Energy Systems: Wind and Water Power	3	X	X	ME EN 2450 Numerical Methods for Engineering Systems	3	X	X
ME EN 2510 Introduction to the Design of Sustainable Energy Systems: Thermal and Solar Power	3	X	X	ME EN 2300 Thermodynamics I	2		
	12	4	4		11	3	3

After two years of teaching the revised courses, student evaluations and faculty observations indicate the changes have been positively received. Faculty members are working closely together to continually improve the courses, faculty enthusiasm is high, and student evaluations are markedly improved. Some concerns remain (e.g., ME EN 1000) and are being addressed, while all classes continue to be reviewed.

Note on Continuous Improvement

The current curriculum is viewed as a marked improvement by both students and the faculty. However, the need to modify courses to keep them current and continuously improve is ever-present. The process undertaken here has motivated the department to look at new ways to continually improve and have smooth transitions as instructors change. One key aspect to this has been the use of Canvas as a vehicle to develop the courses. This allows instructors to efficiently implement changes/corrections in the course and easily transfer the materials for other instructors to teach. Each instructor can make his/her own additions and improvements to the class, ensuring that it will be continually improving each time it is taught.

ACTION 6. Revise ME EN 1000⁴ to improve organization, improve physics coverage, better connect lectures to labs, and streamline instruction on oral presentations

Date: Implemented Fall 2013 (SPIRAL revision) and ongoing

Basis for Action: Student feedback (both course evaluations and exit survey data) indicated the following: 1) the ME EN 1000 course content was perceived as disorganized, 2) some course material, especially the physics coverage, was overwhelming, and 3) lecture material was not adequately connected to the laboratory content. In addition, faculty feedback indicated that students were struggling with the preparation and delivery of oral presentations in upper division courses. In particular, students were casual and used informal language, and lacked organizational strategy in their oral presentations.

Results: The SPIRAL Review Committee thoroughly reviewed the ME EN 1000 content and the course objectives were clarified. The instructor has made significant effort to streamline the content and present it in a more cohesive format, as well as to reduce the number of lab and project assignments.

The physics material has been updated to include more examples and related homework, providing more practice for the students (most of whom will take PHYS 2210 Physics for Engineering I the following semester). Also, ME EN 1000 is now being offered every semester, which allows students who start the program without a solid background in math and physics to delay taking the course for one semester with minimal effect on time to graduation.

More lab material has been worked into the lectures, and more lecture time is spent reviewing the objectives and expectations in the lab. Students are also required/strongly encouraged to bring a computer to class to follow along during lecture and participate during in-class instruction using CAD and Excel.

The overall revisions to the four SPIRAL courses resulted in focused coverage of oral presentations in ME EN 1000 (instead of distributed throughout the four courses). Formal instruction is provided by CLEAR instructors about the 3 Laws of professional communication, and acceptable presentation formats and styles. Students are assigned both written and oral project-focused assignments to practice these skills. For example, students prepare and narrate a formal video presentation to illustrate robot functions. Students also prepare and deliver a focused presentation that summarizes their design project experience. These presentations are graded with a detailed rubric, and peers in each lab section also provide written feedback on strengths, weaknesses, and suggested areas for improvement. Since these changes were implemented, presentation quality has improved, and students have demonstrated the ability to determine what to present and how to organize the material from their project report into a presentation format.

While significant improvements have been made, this course is receiving continued scrutiny and is likely to be further revised in Fall 2015 to address persistent and common instructor and student concerns.

⁴ Formerly: Introduction to the Design of Robotic Systems I; Currently: Introduction to Mechanical Design for Engineering Systems

ACTION 7. Revise ME EN 1010⁵ to provide more focused programming instruction, while keeping a hands-on project

Date: Implemented Spring 2014 (SPIRAL revision)

Basis for action: ME EN 3200/3210 Mechatronics I/II surveys and instructor experience indicated that the SPIRAL ME EN 1010 was not sufficiently preparing students for the programming required in upper-level courses. ME EN 1010 exam results also indicated many students were struggling with programming. In addition, student course evaluations and survey results indicated that the class had too many assignments and required too many hours of work outside of class. Lastly, student survey results and instructor experience indicated that students appreciated having a hands-on mechatronic device and robotic competition to apply their programming skills.

Results: The lecture and lab content were completely redeveloped to focus more on programming skills. Mechanical design content and lectures on economics/safety/ethics were removed to make room for more programming content. Students now receive formal instruction in both MATLAB and C programming. The project and competition were redesigned to remove the mechanical design aspects and focus exclusively on programming. The weekly lab experiments and homework assignments (one integrated assignment per week) were carefully synchronized and designed to guide students towards completion of the project code required for the competition. The course title was changed to Computer-Based Problem Solving for Engineering Systems to reflect the nature of the new course. An ASEE conference paper discussing the revised class is available for review by the evaluation team. Course evaluations have improved significantly since the course was revised, the new design project has been well-received, and students are demonstrating proficiency in both C and MATLAB programming. The first cohort of students will take ME EN 3200/3210 Mechatronics I/II in Fall 2015, after which the longer-term effectiveness of the revised course will be evaluated.

ACTION 8. Revise ME EN 2500 to return focus to numerical methods instruction, revert to ME EN 2450 catalog number

Dates: Implemented Fall 2013 (SPIRAL revision)

Basis for action: End-of-course surveys, course evaluations, and exit survey data for 2010, 2011, and 2012 (SPIRAL) indicated that 1) the workload for ME EN 2500 Introduction to the Design of Sustainable Energy Systems I was too high and 2) the depth of the design project was diluting the value of the numerical methods content. In addition, the faculty instructors felt that the content was disorganized and observed that students had trouble seeing the connection between the various components of the course and the sustainability theme.

Results: As a result of the SPIRAL review, the ME EN 2500 labs, project, and lectures were revamped to make the workload more appropriate for a three-credit course. The lab component of the course was maintained but reduced, with the remaining MATLAB and Arduino microcontroller labs all having relevance to Numerical Methods. In addition, the year-long SPIRAL design project was modified to be a single-semester design project that is entirely

⁵ Formerly: Introduction to the Design of Robotic Systems II; Currently: Computer-Based Problem Solving for Engineering Systems

virtual (nothing is purchased or built). While the design process is highly deemphasized, and the revised project is better aligned with the purpose of the course, the project still requires a sophisticated systems analysis and simultaneous solution of multiple ODEs. Lastly, several lectures on physics (relevant to the SPIRAL project) as well as sustainability and technical writing/oral communication lectures were eliminated. The catalog number was reverted to the pre-SPIRAL number (ME EN 2450) to better articulate with other Utah schools, and the course title was changed to Numerical Methods for Engineering Systems to reflect the core competency of the course.

Course evaluations have been much better since these changes were made. In addition, instructor interactions with students as well as student comments in course evaluations indicate that the new ME EN 2450 class is more in line with a three-credit course.

ACTION 9. Restore ME EN 2510 to a traditional thermodynamics course focused on the first and second laws, revert to two credits and ME EN 2300 catalog number

Date: Implemented Spring 2014 (SPIRAL revision)

Basis for action: Data from course evaluations, exit interviews, and instructor interviews for ME EN 2500 Introduction to the Design of Sustainable Energy Systems II indicated that 1) the teaching style based on an inverse paradigm (where students were expected to learn the material by reading the textbook, and then ask questions and work on problems during class, with no formal lecture presented) was ineffective for the majority of students, 2) the laboratory component (which included Arduino programming and the design and fabrication of an air-powered train) was perceived as disconnected from the course, made the course feel disorganized, and did not contribute to an understanding of thermodynamics, 3) students had difficulty learning thermodynamics due to the significant amount of other material in the course (e.g., labs and design project), and 4), students had insufficient knowledge of introductory thermodynamics for ME EN 3600 Thermodynamics II, where several lectures had to be devoted to reviewing the first and second laws of thermodynamics.

Results: ME EN 2510 was converted back into ME EN 2300 Thermodynamics I, which is a two-credit classical thermodynamics class devoted to the first and second laws. A classical teaching style was adopted in ME EN 2300, where the instructor teaches the fundamentals of thermodynamics and solves relevant engineering problems during the lectures. The laboratory component and designed project were removed, since it did not contribute to the overall objective of the class (i.e., learning and applying the first and second laws of thermodynamics).

The new version of ME EN 2300 was offered for the first time during the Spring 2014 semester and has been offered four semesters in total (including summer semester). Course evaluations for ME EN 2300 have been excellent (above the departmental average). Students feel that they acquired a solid background of the first and second laws of thermodynamics in this course. In addition, feedback from instructors of ME EN 3600 (A. Smith and K. Park) has also been extremely positive since the changes to ME EN 2300 were implemented. The instructors felt that students who took ME EN 2300 were more prepared for ME EN 3600 than students who took ME EN 2510, but no data have been collected.

ACTION 10. Move ME EN 2650 Concurrent Engineering I: Manufacturing from the sophomore level to ME EN 4060 Manufacturing Practices at the senior level

Date: Implemented Fall 2011

Basis for Action: In the SPIRAL curriculum, introductory manufacturing content was distributed throughout the four freshman/sophomore SPIRAL courses. This provided an opportunity to add more quantitative content to the manufacturing curriculum and provide a rigorous manufacturing experience while students were engaged in capstone design by shifting the dedicated manufacturing course to the senior level.

Results: The restructured senior-level manufacturing course was offered for the first time in Fall 2011. The junior-level courses ME EN 3300 Strength of Materials and ME EN 3650 Heat Transfer were added as prerequisites, and the quantitative and analytical content in the course was enhanced. Student feedback and the instructor's experience suggested that important manufacturing information was now being delivered rather late in the curriculum for the information to be effectively utilized. Furthermore, the fact that students were taking the manufacturing laboratory at the sophomore level and not receiving the lecture content until the senior level resulted in a severe disconnect between observational and quantitative advanced learning.

ACTION 11. Restore ME EN 4060 Manufacturing Processes to the sophomore level as ME EN 2650 Manufacturing for Engineering Systems

Date: Implemented Fall 2014

Basis for Action: As an outcome of the SPIRAL curriculum review (Summer 2013), the SPIRAL classes were significantly modified to move the introductory manufacturing content from those classes (ME EN 1000, 1010, 2500, and 2510) back to the manufacturing lecture course. In addition, student and instructor feedback for ME EN 4060 indicated that the move of the manufacturing lecture course to the senior level was undesirable, since the content was covered so late in the program that students could not effectively use the information in their design courses.

Results: In Fall 2014, the manufacturing lecture course was restored to the sophomore level as ME EN 2650 Manufacturing for Engineering Systems to ensure that manufacturing content is being provided early enough in the curriculum for it to be effective in the junior and senior years. During a transition period, ME EN 4060 is still being offered to accommodate students who were expecting to take manufacturing during the senior year. ME EN 2650 and ME EN 4060 meet together for lecture, but the students enrolled in ME EN 4060 receive homework and exam questions at a higher level. Once the class transitions completely back to the sophomore level, the course content will be standardized to one single core content.

ACTION 12. Modify the ME EN 2655 Manufacturing Laboratory curriculum such that the course is no longer the training requirement for students to be authorized for future machine shop use, and shift focus from hands-on experience with mills and lathes to measurement, metrology, and analytical skills

Date: The curriculum committee reviewed this proposal early Oct 2014. Implemented in Fall 2014 after faculty vote on November 11, 2014.

Basis for Action: Due to increasing student throughput, the historical use of ME EN 2655 Manufacturing Laboratory (or ME EN 2660 Machining Laboratory for students in the SPIRAL curriculum) as the means to train students as machinists came up for discussion in the Curriculum Committee. Lab instructor input suggested that requiring complete training and safety instruction in ME EN 2650 Manufacturing for Engineering Systems for each student in the program was difficult due to space, infrastructure, and instructor constraints. For example, teaching two students at a time on a machine was not considered prudent for both safety and training effectiveness.

Results: The ME EN 2655 lab was redeveloped to emphasize measurement and analysis to understand the effect of manufacturing processes on design specifications. Specific training to use the machines in the machine shop was shifted to individual training modules that were addends to the curriculum rather than being completely integrated into the formal curriculum (see ACTION 14). The new measurement- and analysis-based lab curriculum was offered for the first time in Fall 2014. While it had been anticipated that the revised lab could accommodate 12 students per section (compared to 6 students per section in the original lab), the instructor was more comfortable with 9 or fewer students per section. As a result, the new lab paradigm did not sufficiently alleviate the machine shop load to make room for training modules and open hours for juniors and seniors to use the machine shop for course projects.

ACTION 13. Eliminate ME EN 2655 Manufacturing Laboratory and integrate demonstrations of manufacturing processes into the ME EN 2650 Manufacturing for Engineering Systems lecture course

Date: Proposed to the curriculum committee and the faculty in Fall 2014; Implemented in Spring 2015.

Basis for Action: Section size limitations for the newly implemented (Fall 2014) measurement- and analysis-based ME EN 2655 curriculum failed to relieve bottlenecks in shop availability. In addition, course evaluations and exit interview data for ME EN 2650 and ME EN 4060 indicated that students felt they would benefit from observations of the various manufacturing practices.

Results: The standalone ME EN 2655 manufacturing lab was eliminated from the curriculum, effective Spring 2015. The demonstration- and observation-based activities from ME EN 2655 were incorporated into the ME EN 2650 lecture course as four 90-minute sessions per semester. The “demo lab” activities are coupled to assessment based on additional related material provided during lectures. This change resulted in a six-fold reduction in machine shop usage, which has significantly improved the ability of the shop to provide training modules throughout the semester (see ACTION 14) as well as open shop hours. As such, the bottlenecks in machine shop availability have been addressed. In addition, the integration of the demo labs into the

lecture course has addressed the previous disconnect between observational and quantitative advanced learning.

ACTION 14. Develop specific training modules for basic equipment, lathe, and mill to train students for independent operation of equipment in the student machine shop

Date: Fall 2014

Basis for Action: The significant increase in the student population over the past decade without corresponding expansion of the machine shop space and resources made it untenable to provide complete training and safety instruction in ME EN 2655 Manufacturing Laboratory for each student in the program due to space, infrastructure, and instructor constraints.

Results: The department implemented a new paradigm for students and the faculty to access the machine shop in order to ensure safe operation of the machine shop equipment. Rather than training every student enrolled in the mechanical engineering undergraduate program to use the equipment in the machine shop, it is now made available to students on a voluntary basis, i.e., only students with an aptitude and interest in manufacturing obtain specific training to independently use the machine shop. The new training paradigm consists of three separate modules. The “basic” module covers shop safety, metrology, machine set-up and cleaning, drill press, and basic hand tools. Once a student has passed this module, he/she can enroll in a “lathe” module and a “mill” module, which provide specific training on the respective machines. The modules are structured to provide approximately the same number of hours of training on the milling machines and lathes as in the prior required, semester-long laboratory course. New online and printed materials have been developed for training purposes, to document procedures and practices, and to assess student performance. In addition, a badge system has been implemented to control access to the machine shop.

The change has been well-received by students, as evidenced by end-of-module surveys. While a complete picture of the benefits and shortcomings (if any) will not be available for another academic year, when a full cohort of students who received only the module training works its way through the Mechatronics and Capstone Design courses, the assessment of student competence to-date by the lab technicians indicates that the new modules are providing the desired outcomes and safety/skill levels.

ACTION 15. Design and begin implementation of shop upgrades

Date: Spring 2014

Basis for Action: The Curriculum Committee (CC) was tasked by the Department Chair to propose modifications to the existing machine shop in order to better meet the current and projected curricular and research needs of the students and faculty members in the Department. In addition, safety concerns were raised during the 2011 Graduate Council Program Review of Mechanical Engineering.

Results: The CC spent about four months during the 2013-14 academic year drafting a proposal for modifications to the shop (full report available in ABET program review materials). The proposal addresses the safety concerns that were raised in the 2011 Graduate Council Program Review of Mechanical Engineering, and also addresses other concerns raised by the faculty in terms of limited resources and shop training. The proposal outlines the existing resources and

identifies the future resources that would be necessary to alleviate safety concerns and to accommodate the shop demands in the areas of teaching and research needs. The proposed organization of the shops follows a four-tier structure including a basic shop, an educational shop, an advanced shop for student use that includes access to CNC machines as well as welding facilities, and a professional shop. Students gain certification to the shops through a series of training modules. A preliminary skeleton of the content of each training module is provided in the proposal. The proposal also suggests a layout for the shops that emphasizes safety but will also be appropriate to manage the expected throughput of students and allows for further growth. Finally, the proposal outlines a strategy for restricting access to the shops and machines in the shops, monitoring users in the shops, and streamlining the certification process via a dedicated shop website. Twenty-one recommendations were given at the end of the proposal.

Results: Training modules have been implemented during the 2014-15 academic year. The bulk of the proposed changes require substantial renovation to the existing space. The Dean of the College of Engineering is supportive of the shop proposal. In fact, it was the Dean's number one item on the COE request for one-time Engineering Initiative funding. The dollar amount slated for shop renovations is on the order of \$200K.

ACTION 16. Perform major review of curriculum

Date: 2014-2015 academic year

Basis for action: broad range of all ABET assessment tools. This action began as a review of the communication coverage, and grew into a full review of all major components of the curriculum.

Results: A set of major and minor curriculum revision recommendations is slated to be presented and discussed at the Fall 2015 faculty retreat meeting. Recommendations are based on evaluation using a hierarchical framework as follows:

1. Primary Considerations
 - a. Course supports material covered in higher level courses
 - i. Added course serves as a prerequisite to other courses in the program
 - ii. Added upper-division course supports an emphasis (i.e., is a prerequisite for an intermediate or advanced course at the 5000/6000 level)
 - iii. Minimal overlap between courses
 - b. Course contributes to one or more ABET criteria
 - c. Resource demands (personnel and/or facility)
 - d. Workload magnitude and distribution (students and faculty)
 - e. Pedagogy (documented versus hypothesized)
 - f. Uniqueness of Utah ME program – hands on learning via lab and design experiences
2. Secondary Considerations
 - a. In line with peer institutions (top 30 + PAC-12)
 - b. In line with ASME 2030 vision
 - c. In line with Industry needs
 - d. Supports research mission of Department – training of prospective graduate students and undergraduate researchers
3. Tertiary Considerations
 - a. Impact on other departments
 - b. Student interests (student polls)

- c. Articulation agreement – impact on transfer students
- d. Added value/additional material coverage

The main recommendations are summarized below. For each recommendation, a pro versus con list was completed based on the evaluation framework (details are provided in the materials available to the evaluator during the visit). The Curriculum Committee considered available data where appropriate, including FE Exam performance results, comparison with peer institutions (top 30 schools plus the PAC-12 schools), ASME 2030 Vision, student surveys, and student evaluations in existing courses.

Proposed Recommendations:

1. Add 3 credit hour Technical Communication course at junior level
2. Add 3 credit hour Statistics course at sophomore level
3. Decouple TFES labs from lecture and add a standalone TFES lab; this assumes that the standalone TFES lab course will introduce a new design project so that the new lab course is more than the sum of the individual labs from each of the three TFES courses
4. Switch to engineering math sequence
5. Remove ME EN 3900 Professionalism and Ethics Seminar – writing content moved to new Technical Communications course; presentations by industry possibly moved to ME EN 4000 Engineering Design I or provided through a non-mandatory undergraduate seminar series
6. Remove 1 credit hour from ME EN 1300 Statics and Strength of Materials – overall reduction in required strengths content; material not covered in ME EN 3300 Strength of Materials is moved to ME EN 5300 Advanced Strengths
7. Remove 1 credit hour from ME EN 2080 Dynamics – likely move material not covered to the appropriate technical elective
8. Combine ME EN 2300 and 3600 Thermodynamics I and II into one junior-level Thermodynamics course – overall reduction in required thermodynamics content; material not covered at 3000-level is moved to ME EN 5600 Intermediate Thermodynamics
9. Modify ME EN 3200 Mechatronics I to be a standalone 4 credit hour mechatronics lab/project course – keep ME EN 3200 lab and two-thirds of the original lecture content including sensors, actuators, signal conditioning, microcontrollers, etc. (+3 credit hour worth), eliminate kinematics and mechanisms content (-1 credit hour worth), and add the project component of ME EN 3210 Mechatronics II (+1 credit hour worth); the kinematics and mechanisms content that is eliminated will be redistributed into ME 1000 Introduction to Mechanical Design for Engineering Systems, ME EN 3000 Design of Mechanical Elements, and ME EN 4000 Engineering Design I.
10. Convert ME EN 3210 Mechatronics II into a 3 credit hour lecture course entitled “Dynamic Systems and Controls;” lab/project content moved into separate standalone course (see recommendation 9)

ACTION 17. Create stand-alone communications course

Date: February 2015

Basis for action:

- In 2013, the College of Engineering, which provides the financial support for CLEAR (Communication, Leadership, Ethics, and Research), decided to change their staffing model by moving to permanent staff and discontinuing the employment of Ph.D. students from the Department of Communications. As a result, fewer staff are employed by CLEAR, which prevents the department from staffing lab and writing-intensive courses with individual CLEAR staff.
- Student feedback has indicated that the participation of CLEAR instructors in various courses throughout the curriculum has not been very helpful. Because the CLEAR instructors were historically Ph.D. students from the Department of Communications, the instructors often changed year-to-year, resulting in a loss of continuity and the need to relearn effective practices each year. In addition, feedback on writing assignments was often inadequate for learning due to class size (>120 students typically).
- Written communication has been observed to be weak in several classes, resulting in ad hoc communications instruction such as breaking up final reports in ME EN 5510 Introduction to Finite Elements into lab assignments for which feedback was given incrementally. Similarly, one instructor of ME EN 1300 Statics and Strength of Materials required students to follow a systematic format (given, required, solution, discussion) for presentation of solutions.
- Student feedback (course evaluations and exit interviews) indicates that students think there is too much writing as part of ME EN 4000 Engineering Design I, detracting from the actual design process. (Note that this course currently satisfies the University's Upper Division Communication/Writing (CW) requirement, so extensive writing must be included.)

Results: In the new CLEAR model, the Department of Mechanical Engineering has been assigned a single CLEAR instructor (Russ Askren). In response to the CLEAR staffing changes, the department is currently developing a stand-alone 3-credit course on technical communication to be taught by the CLEAR instructor, which is expected to improve instruction on written and oral communication. A pilot version of the course was offered as an elective in Spring 2015. Upon approval by the faculty (slated for discussion at the Fall 2015 Faculty Retreat), the Upper Division Communication/Writing designation will be requested for this course, which will make room for additional technical content in ME EN 4000 Engineering Design I.

The stand-alone course contains significant instruction on various aspects of written and oral communication, including audience, purpose, and context. Assigned readings and assignments address the specific issues of audience, purpose and context. All students make two presentations, the first as an individual presentation and the second as a group presentation on a collaborative writing project. All presentations are video-taped and students complete self-evaluations of their presentations based on those tapes. The construction of effective posters is included. Students produce significant written work where the focus is on purpose, context and style. Students have a written assignment in which they write a short document explaining a basic engineering concept for both lay and peer audiences (in Spring 2015, students explained the purpose and construction of a free body diagram for a wheel rolling down an incline). Students are also required to peer review both written and oral work.

ACTION 18. Create required sophomore-level statistics course

Date: Analysis 2014-2015 academic year

Basis for action: Faculty on the Curriculum Committee provided anecdotal evidence that ME undergraduates in upper-division classes, senior design, and some technical elective classes lack sufficient knowledge and skills in statistics. There is also direct evidence via student performance on the FE exam that shows Utah ME students consistently scored below the national average in the area of probability and statistics in the last five years. Finally, a student poll of juniors indicates that the majority of students are supportive of adding a statistics course. Also in the student poll, students were asked “which of the following topics should be covered in the ME curriculum?” Out of a list of 15 different topics related to probability and statistics, 80% of respondents said that “Design of Experiments” should be covered and 65% of respondents said that “Tolerance Analysis” should be covered. Data are available in the proposal written by the Curriculum Committee (available upon request and archived in the materials available to the program evaluator). Currently statistics is only formally taught for two and a half weeks in ME EN 3000 Design of Mechanical Elements.

Results: The Curriculum Committee is recommending that a standalone statistics course in the second year be required for the BSME. In order to avoid adding additional credit hour requirements to the BSME, the Curriculum Committee suggested removing credit hours from other courses. These are detailed in the aforementioned proposal. The proposal will be presented at the 2015 ME Faculty Retreat.

ACTION 19. Revise the Statics portion of ME EN 1300 Statics and Strength of Materials to be taught over a full semester

Date: Analysis 2014-2015

Basis for action: The ME EN 1300 course has long been a four-credit combination of Statics with an introduction to Strength of Materials, which necessarily made the Statics part of the course taught over an accelerated time frame (about 2/3 to 3/4 of a semester). End-of-course evaluations strongly indicated that the class should be refactored to not be covering two topics (statics and introduction to strengths) in a single semester. Direct observations of performance in homework and quizzes tended to support the need for extended time on statics. Feedback from ME EN 3300 Strength of Materials also indicated a redundancy of strengths topics in ME EN 1300 being repeated in ME EN 3300. Articulation of transfer credit was also difficult, as students who had taken a full-semester statics course elsewhere were required to take the introduction to strengths portion of the class as a 1-credit independent study; these students therefore had nothing to do for more than two thirds of a semester, only to find themselves in a class moving at a 4-credit pace over the trailing part of the semester; the result was that these transfer students had *significantly* higher failure rates than those taking the full 4-credit class.

Results: This course will likely be changed to a traditional 3-credit Statics course in Fall 2016. This change, which is slated to be brought to the Fall 2015 retreat by the curriculum committee, will entail a reduction in credit hours from 4 to 3. The effect of all curriculum revisions on Engineering Topics credit accounting will be examined at the Fall 2015 retreat.

ACTION 20. Improve the teaching of mathematics

Date: Implemented Spring 2008

Basis for Action: Faculty team review of ME EN 1300 Statics and Strength of Materials and ME EN 1000 Introduction to Mechanical Design for Engineering Systems, as well as feedback from exit interviews and direct assessment of student's mathematical abilities at the beginning of ME EN 3200 Mechatronics I triggered an examination of the teaching of mathematics at the University of Utah as well as local community colleges. Students in ME EN 5500 Engineering Elasticity were unprepared for and often unhappy about solving differential equations. Linear algebra preparation in ME EN 5510 Introduction to Finite Elements and ME EN 5530 Introduction to Continuum Mechanics was observed to be initially weak, but corrected during the course through coaching. Basic knowledge of multivariate calculus (chain rule, volume integrals, coordinates, etc.) also had to be re-taught in ME EN 5530.

Direct evaluation of poor math preparation (including trigonometry, algebra, and calculus) was conveyed (by freshman- and sophomore-level course instructors) to the curriculum committee and administrators on a regular basis throughout the early part of this ABET review cycle. Direct assessment of math skills was done using pre-tests that were administered during the first day of class. Poor math performance has also been observed for the past 5 years on the FE Exam by Utah ME students. A desire to remedy this situation led to the creation of a College Math Committee that resulted in a new Engineering Mathematics initiative. Faculty representatives from all of the engineering departments and the Department of Mathematics meet regularly to oversee the design and college-wide implementation of a new 4-course engineering math sequence offered through the Department of Mathematics. The effectiveness of the new engineering math sequence is being assessed by the College. Its effect on student performance in the lower-division ME courses should be clear by the next review cycle.

Results: Together, the above assessments led to a major initiative at the College level to develop a new 4-course engineering mathematics sequence (16 credits total) taught by the Department of Mathematics that includes more physics and engineering applications compared to the traditional mathematics sequence. Applications are provided by engineering faculty members working in conjunction with the College Math Committee. See Criterion 4A for details and assessments. In 2013, Dr. Brannon met with W. Neese (who designed and oversees this new math sequence) to review the new physics-based assignments and to discuss the need for assessing outcome-focused achievement in addition to the student-retention and time-to-completion metrics. In a follow-up email exchange, it became clear that the low level of linear-algebra coverage (namely, a total of only six weeks of instruction in which the concept of positive definiteness is skipped) was likely to contribute to marginal direct assessments of this topic (see Section A).

ACTION 21. Provide instruction on successful implementation of teamwork

Date: Extending the introduction of major teamwork instruction revisions that were put into place in 2004, this action was continually assessed and revised continually through this cycle

Basis for Action: Although outcome assessment indicated that students were obtaining sufficient opportunities to work on teams as part of their educational experience, serious concerns existed regarding the level of teamwork that actually occurred when students were required to work in groups. A specific concern with respect to ME EN 4000/4010 Engineering Design I/II is that

not all team members contribute sufficiently to the project, and there is not sufficient individual accountability.

Results: In the previous review cycle, the CLEAR Program began teamwork instruction in ME EN 1000 (at that time, entitled Design and Visualization). Students are introduced to team formation, the importance of roles, common difficult behavior types, and the development of a team working agreement (or contract). This instruction is reinforced in ME EN 4000 Engineering Design I by CLEAR instructors. Teams are usually required to create a team working agreement. Furthermore, teammate evaluations are submitted twice during the semester. The first time does not affect the students' grades, but is just used as a feedback mechanism for team members. The second teammate evaluation does affect the students' grades. Finally, the specific concern about individual accountability is being addressed by increasing the percentage of the total grade that is individual, rather than team based. So, for example, faculty project advisors give each member on the team an individual grade based upon his or her contribution to the team.

ACTION 22. Add new technical electives

Date: throughout review cycle

Basis for action: The addition of new faculty members provided an opportunity to expand and modernize course offerings to better cover skills desired from industry.

Results: The following new technical electives have been added to the curriculum since Fall 2009. Courses are typically offered as ME EN 5960 Special Topics for the first two offerings. All of the ME EN 5960 courses listed below are expected to move to real catalog numbers early in the next ABET cycle.

- ME EN 5205 System Dynamics
- ME EN 5250 Object-Oriented Programming for Interactive Systems
- ME EN 5535 Biomechanics I
- ME EN 5540 Biomechanics II
- ME EN 5730 Microfluidic Chip Design and Fabrication
- ME EN 5960 Nanotribology and Contact Mechanics
- ME EN 5960 Nanoscale Heat Transfer
- ME EN 5960 Wind Energy
- ME EN 5960 Integrated Energy Systems Analysis
- ME EN 5960 Intermediate Heat Transfer
- ME EN 5960 Fundamentals of Electromagnetic Transducers

ACTION 23. Improve advising of technical electives through introduction of emphasis areas

Date: Fall 2013

Basis for action: The faculty team review of ME EN 5500 Engineering Elasticity revealed that students did not seem to understand what the course covered before signing up. This problem is reflected in student feedback, sometimes with students questioning the value of a course for their careers.

Results: Similar observations for other tech electives have motivated the introduction of emphasis areas to better advise students to take courses that are pertinent to their career objectives.

ACTION 24. Add contemporary measurement techniques in ME EN 5700 Intermediate Fluid Dynamics

Date: February 2015

Basis for action: Faculty team review of ME EN 5700

Based on instructor evaluations, a need was identified to keep up with latest fluid mechanics measurement technology.

Result: New PIV and flow visualization methods labs were added and older technology labs were eliminated. Students were exposed to some of the most current visualization and quantification methods in fluid mechanics.

ACTION 25. Develop a simple outcome-focused direct assessment process that uses start-of-term prerequisite knowledge quizzes and homework

Date: First prototype Fall 2011; informal testing 2012-2015; anticipated broader implementation Spring 2016.

Basis for action: In the mid-cycle ABET review, the program assessment process was identified to have room for improvement in direct assessment with greater focus on *outcomes* rather than *courses*. With regard to Outcome 1, the faculty review of ME EN 5530 Introduction to Continuum Mechanics sample student work revealed insufficient preparation in basic prerequisite math (observed from low homework and exam scores that specifically tested for prerequisite skills in linear algebra and multivariate calculus, which is crucial to Criterion 9). Anecdotal evidence about other courses (typically instructor commentaries in department meetings) showed a general theme that outcome-specific preparation could be better tested by direct assessment of prerequisite preparation in senior-level technical-elective courses. For the last three offerings of ME EN 5530, a direct assessment of prerequisite knowledge has consistently indicated that linear algebra, multivariate calculus, and coordinate systems are not adequately understood by the students.

Results: As part of a multi-year informal experiment, a few professors started to assign a “homework zero” or “welcome pop quiz” on the first day of class to cover only prerequisite knowledge. Such assignments were initially viewed as a “wake up call” to warn students about information they are expected to know before coming into a course. In that respect, they seemed to foster better performance in the class itself. It was later recognized that these day-one prerequisite skills assignments could also serve nicely as outcome-specific direct assessments.

In Fall 2011, a first step to formalize this idea was taken by designing a simple Excel spreadsheet to illustrate how prerequisite skills could be tested in each class by asking specific questions that directly assess specific outcomes that are pre-requisites for the class. Following successful experiment results (for both outcome assessment for ABET and prerequisite reviews for students), implementation of this idea across the curriculum is to be proposed at the 2015 Faculty Retreat.

ACTION 26. Implement twice-per-year offerings of all required undergraduate courses

Date: Spring 2013

Basis for action: Student-teacher ratio growth and increasing class enrollments, as well as a desire to improve retention and graduation rate by making the program more flexible

Results: As detailed in Criterion 7.C (Faculty Size), Engineering Initiative funding allowed the program to hire 6 new faculty members, which then allowed offering required courses twice per year.

ACTION 27. Formalize graduate instructor mentoring

Date: Slated for Fall 2015

Basis for action: Student reviews have been mixed regarding effectiveness of graduate students as instructors

Results: Historically, faculty mentors have been assigned to monitor graduate students who are instructing classes, and this responsibility is to be extended to require a report. Furthermore, graduate student instructors will be required to have at least one of their lecture sessions observed by a Center for Teaching and Learning Excellence (CTLE) staff member.

ACTION 28. Change year-long mechatronics project to a single semester and move all pedagogical labs to the first semester of the sequence

Date: August 2011

Basis for action: Prior to this reorganization, the lab components of ME EN 3200 Mechatronics I and ME EN 3210 Mechatronics II mixed pedagogical laboratory exercises with a two-semester team-based mechatronics project. The project was themed around a year-end robotics competition where the students would begin work in Fall semester and conclude in Spring semester. Fall semester ME EN 3200 laboratory exercises focused on data acquisition, mechanisms, sensing, actuators, and microcontrollers, while Fall semester project activities focused on developing the actuated mechanisms of their project, typically a mobile robot with a manipulator. Spring semester laboratory activities then focused on system dynamics and feedback control, with project activities requiring teams to complete their project by integrating sensors, motor controllers, and microcontrollers to create an autonomous robot for the year-end design competition.

While this process gave students extensive team experience and many opportunities to iteratively improve their project, it presented several major problems that ultimately triggered the proposed action:

1. The first trigger was excessive student workload. Student course feedback, senior exit interview feedback, and feedback from other faculty indicated that the combined

Mechatronics laboratory experiments, project activities, and regular coursework were demanding far too much time and interfering with other classes.

2. The second trigger was that it was virtually impossible to maintain cohesive teams between Fall Semester and Spring Semester. Student schedules could not be aligned and typically only part of the team could be in a given lab section. Hence, typically only part of the team could meet with their TA, which made teamwork extremely challenging.
3. The third trigger was that faculty workload to teach these classes in this format was excessive. The faculty time required to design and run a project like this is significant, and the addition of interspersed pedagogical labs meant that the faculty member was continuously jumping between making preparing project and lab activities. Likewise, since the project started in the Mechatronics I and ended in the Mechatronics II, the process naturally worked better if the same faculty member taught both semesters, which meant a tremendous workload for the entire year. We experimented with different instructors in Mechatronics I and Mechatronics II, but this raised a new set of challenges since it was very hard for the Mechatronics II instructor to pick up where the Mechatronics I instructor left off.
4. The fourth trigger was that most teams re-designed and rebuilt their mechanism at the beginning of Spring Semester in Mechatronics II. While this was very educational from a design perspective, it meant that there was limited time available for embedding sensing, actuation, control, and programming for most teams.
5. The fifth trigger was that the lab and project were plagued by hardware problems which detracted from educational outcomes. Part of this was due to the particular hardware being used in the project and some of the pedagogical lab experiments, but another factor was that the TAs and instructor were constantly bouncing between preparing project activities and lab activities, which made it difficult to stay focused on either task.

Results: To remedy these problems, we moved the pedagogical labs exercises to ME EN 3200 Mechatronics I (typically Fall semester) and the project activities to ME EN 3210 Mechatronics II (typically Spring semester). The rationale was that the students would establish a foundation in ME EN 3200, which would be reinforced by a team-based mechatronics project in ME EN 3210. Condensing the pedagogical laboratory activities into one semester provided an opportunity to also redesign the lab activities to improve their reliability. We also adopted new microcontrollers and motor controller hardware in the project. Per the previously mentioned triggers, the following results were noted:

1. Student Workload: Some students complained that they wanted to have a year-long project, but the student and faculty complaints about the time required for the Mechatronics project and the impact of Mechatronics on other classes virtually disappeared. ME EN 3200 is especially manageable since the lab only involves pedagogical exercises, but the students still need to be reminded to limit their time investment into the project in ME EN 3210.
2. The problem with maintaining cohesive teams between ME EN 3200 and 3210 was eliminated. Teams are now only formed in ME EN 3210 and are only maintained for that class.
3. Faculty workload has been improved. Different instructors can easily teach ME EN 3200 and ME EN 3210, which allows a faculty member to easily teach one of these large classes one semester and a smaller graduate class another. Extra workload associated

with coordinating the project and reorganizing teams and lab sections has been removed. Workload is still high in MEEN 3210 where the project is currently based.

4. Highly structured milestones are used in ME EN 3210 to assure that students balance time for designing/manufacturing their mechanisms and embedding/programming electronic systems. Some teams still design and manufacture multiple prototypes of their mechanisms, but the milestones require the teams to balance their focus on all aspect of the project.
5. Hardware reliability issues have also been resolved. For the ME EN 3210 project, teams are now provided with new Arduino microcontrollers and heavy duty Pololu motor controllers, resolving the major hardware problems in that course. When we condensed the lab activities into ME EN 3200, we also eliminated some of the more delicate hardware, which helped remove some of the problems. We are also able to focus exclusively on the pedagogical labs in ME EN 3200, which has made it easier to keep experimental hardware functioning.

One new complaint from students about the new format is that the pedagogical labs from ME EN 3200 seem mundane without the project immediately tied to them. One option being considered is changing ME EN 3200 to a Mechatronics Lab class that would again combine the pedagogical lab and the project, but in a single semester class and without the typical lectures, homework, and exams. This would enable increased rigor in ME EN 3210 since it would then only focus on System Dynamics and Control.

Faculty members also comment that the project part of ME EN 3210 is still very demanding to develop and implement. The proposed Mechatronics Lab class may help alleviate this. The faculty consensus, however, is that a staff member dedicated to supervising the lab, maintaining experimental hardware, and assisting with projects would be beneficial to further balancing faculty workload and improving student education.

ACTION 29. Adjust communication activities in ME EN 3210 Mechatronics II to reduce emphasis on written communication (already adequately covered in a prerequisite class) to greater focus on presentation skills

Date: Implemented in Spring 2015.

Basis for Action: Student project work and lab reports indicate that students are writing a tremendous amount for ME EN 3200 and 3210, but not gaining much presentation experience besides the poster session at the end of ME EN 3210. As a result, we have changed the milestone reports in ME EN 3210 into a presentation format where students provide short weekly update presentations in lab and provide four major (20 minute) presentations in lab.

Results: This is being implemented in Spring 2015, too soon to analyze data as of this date. Only anecdotal evidence is available, but the students appear to appreciate this change and experience. We will evaluate course reviews and presentation grades to determine if this change was beneficial to the students. We will also consult with ME EN 4000 and 4010 Engineering Design I and II instructors in 2015/16 to see if they notice an improvement in presentation quality. We will also examine exit interview data in 2016, which is when these students are expected to graduate.

ACTION 30. Modernize classical-mechanics technical electives

Date: February 2015

Basis for action: The faculty team review of ME EN 5500 Engineering Elasticity indicated that this course has, in the past, followed a traditional approach of a sequence of simple boundary value problems without proper context of such problems in a modern engineering context, such as the role of these problems in verification testing of finite-element codes.

Results: The Solid Mechanics Group within the department will explore modernization of the course content to combine traditional elasticity content with advanced strengths, plates and shells, mechanics of stability, and the analysis of such problems using modern computing tools. Other technical electives with similar issues will be evaluated.

ACTION 31. Restructure ME EN 5910 Cooperative Education to be taken for 3 credits for full-time summer employment

Date: Implemented Summer 2014

Basis for action: The previous version of ME EN 5910, which was earned one credit per semester, often meant that students would need to register for a single credit during summer semester. However, this was cost-prohibitive due to the nature of the University's tuition schedule. Allowing students to register for the summer credit during the prior Spring or subsequent Fall semester was logistically confusing and disliked by both the Registrar and the Department Chair. In addition, there was concern by the faculty instructor that the quality of the final reports was widely varied.

Result: The ME EN 5910 syllabus and requirements were revised so that students working full time (40 hours per week) can earn 3 credits per semester. Students working a minimum of 20 hours per week can earn 1.5 credits per semester for two semesters in order to complete 3 total credits for technical elective credit. Students must now register for ME EN 5910 in the semester(s) during which they are doing the cooperative internship. To justify the move to 3 credits for a single semester, several new career/professionalism assignments were developed. In these assignments, the students perform a career self-evaluation, develop a career action plan, and reflect on topics such as networking, communication, teamwork, initiative, and ethics as they relate to their internship. A new learning objectives assignment as well as several technical progress reports were also added, which have been successful in improving the quality of the final technical reports. In addition, the employer evaluation was converted to an online survey, and updated to query the employer on the importance of and the student's ability to satisfy the program's ABET outcomes.

ACTION 32. Revise Alumni survey to better serve continuous improvement needs

Date: 2011

Basis for action: In preparation for the 2012 Alumni survey, it was noted that the previous surveys asked for rankings of the importance of various outcome-related skills along with separate rankings of the respondent's *competence* in each of these skills. We realized, however, that a high ranking of competence might be the result of post-graduation continued education (such as company training, workshops, independent study, etc.), which would therefore not serve as any indicator of program success (other than commitment to life-long learning).

Result: The Alumni survey now asks the respondent to rate “the degree to which your formal education prepared you...” This rephrasing, which has been used in the last two Alumni surveys, helps to assess the degree to which *the curriculum itself* (not independent post-graduation studies) contributed to attainment of student outcomes. The previous wording could only serve as assessment of attainment of objectives. Because objective assessment is no longer required by ABET, a natural shift was to reword the questions to become outcome assessments (after the fact).

The distinction between outcome importance and outcome attainment was summarized earlier in this Self Study (in Figure 4A.1), where it was explained how the time delay of the alumni data effectively makes that assessment tool an assessment of the adequacy of our other (faster turn-around time) assessments.

ACTION 33. Mentor new faculty on the use of Center for Teaching and Learning Excellence (CTLE) workshops on “managing large classrooms” and other topics to improve teaching skills

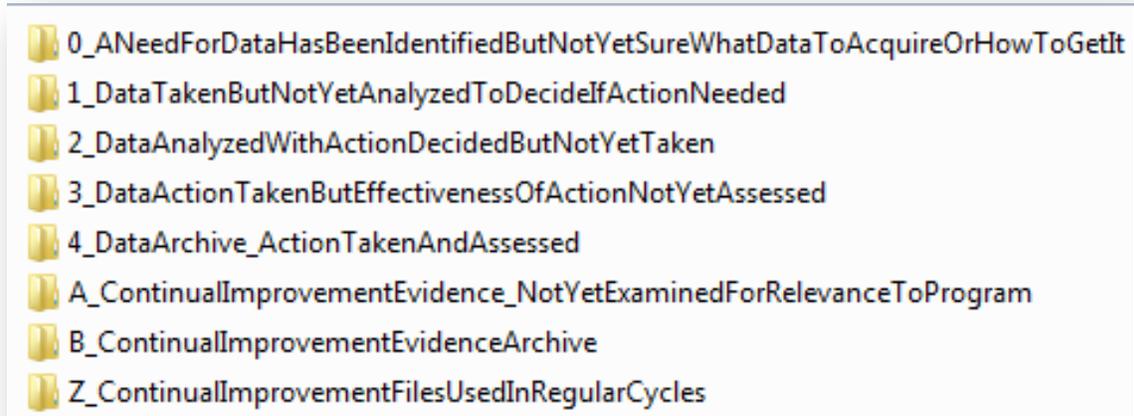
Date: Spring 2011 through 2013

Basis for action: A new faculty member received very low student evaluations for ME EN 3910 (now ME EN 3000 Design of Mechanical Elements) in Spring 2011, mostly because of too much use of PowerPoint slides that were criticized for being highly technical without sufficient example problems. All tenure-track faculty members receive an annual examination of their progress. This process resulted in tenured mentors recommending involvement from CTLE. The new faculty member took this advice in the second half of Spring 2011 and then continued working with the CTLE through 2013.

Result: The services of CTLE led to incremental improvement of the instructor’s course evaluations, ultimately resulting in his becoming the student choice for Outstanding Instructor of the Year 2014 in the Department of Mechanical Engineering.

C. Additional Information

Part of the program’s continuous-improvement process attempts to avoid the common problem of actions being taken without supporting data (or data being taken without being used to improve the program). To mitigate such oversights, the program progressively moves its working files through the following descriptive folder names, which serve as reminders of each step of the assessment process:



For this review cycle, assessment instruments and materials referenced above (in Sections 4A and 4B) are copied from the above-listed “Evidence Archive” and are available for inspection at the time of the visit (or sooner upon request from any member of the evaluation team). Additional information (such as minutes from meetings where the assessment results have been evaluated and where recommendations for action have been made) are also archived here for the evaluator’s convenience.

Appendix X

Employment for Mechanical Engineering Graduates

Career Services Dean's Report



College of Engineering



February 2017

College of Engineering Career Services Liaisons



Francine Mahak

Career Coach

fmahak@sa.utah.edu

801-585-9076



Stan Inman

Director

sinman@sa.utah.edu

801-585-5028



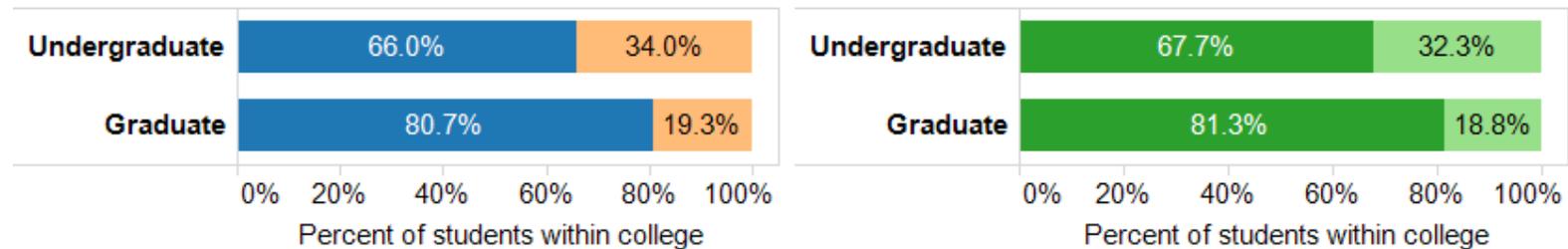
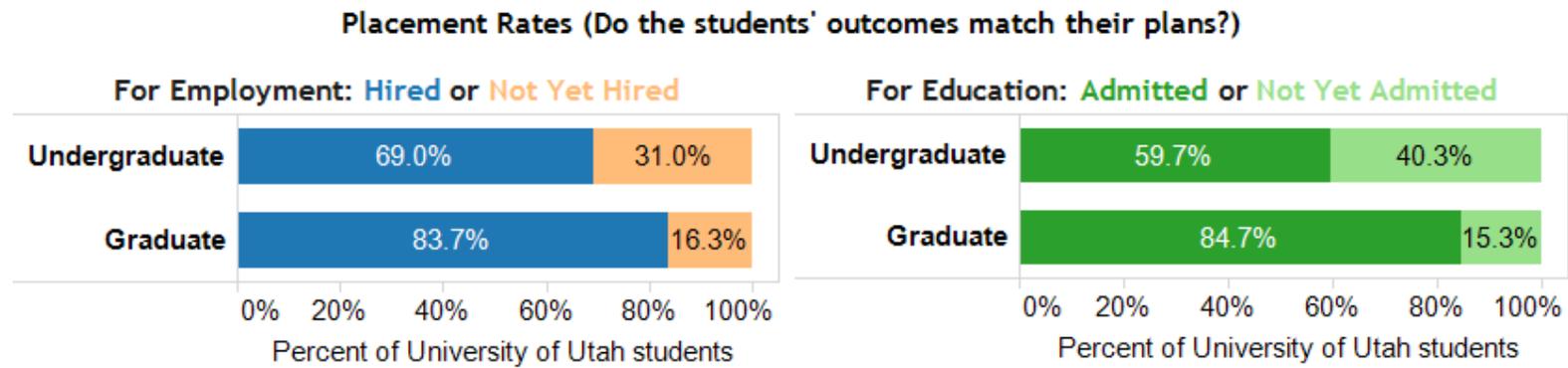
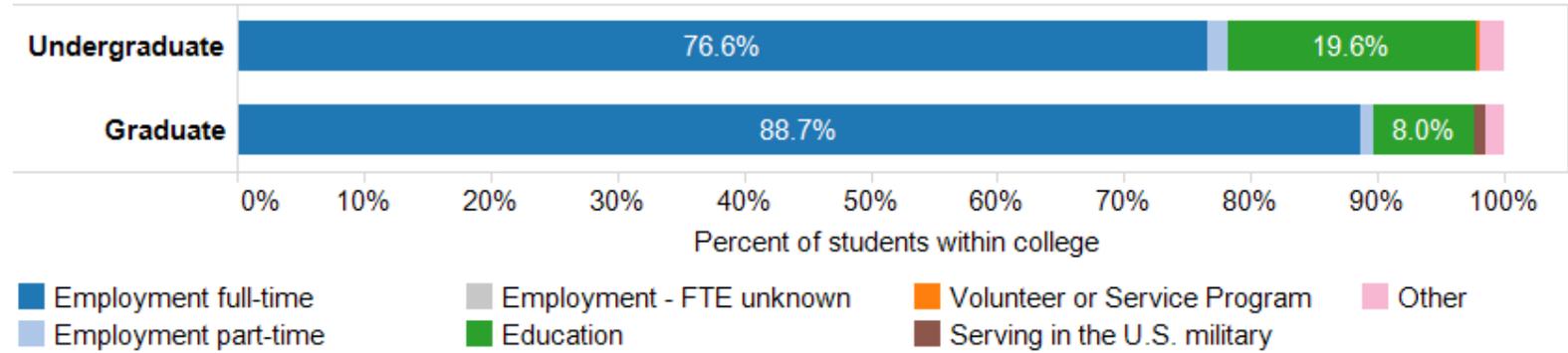
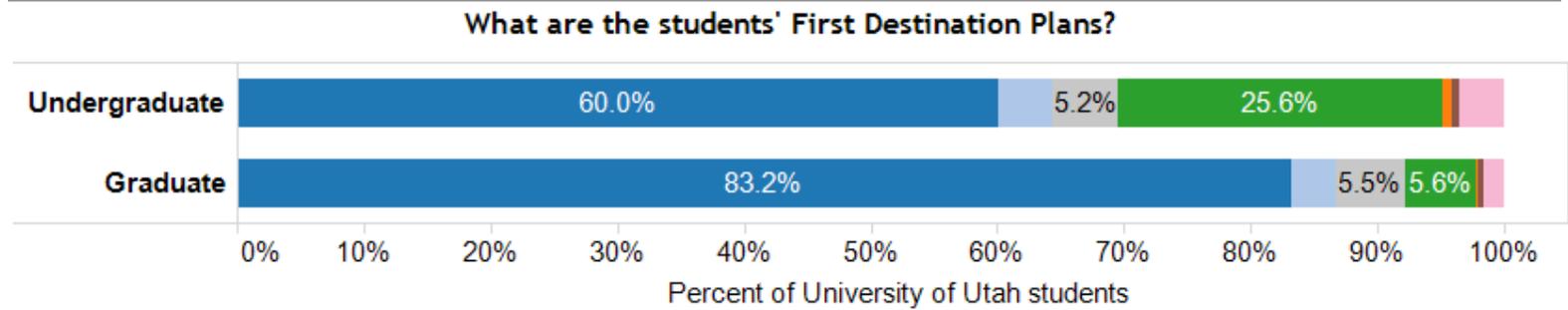
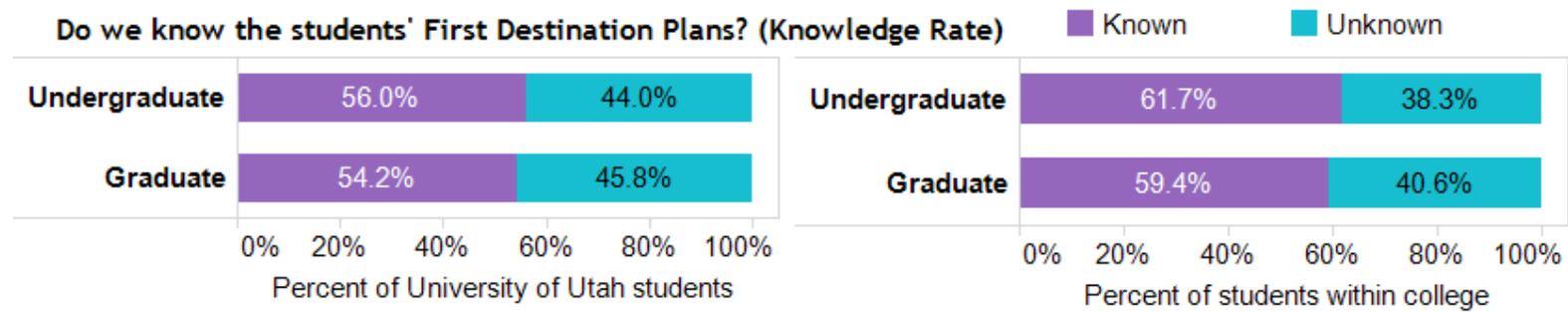
Kelly Dries

Associate Director

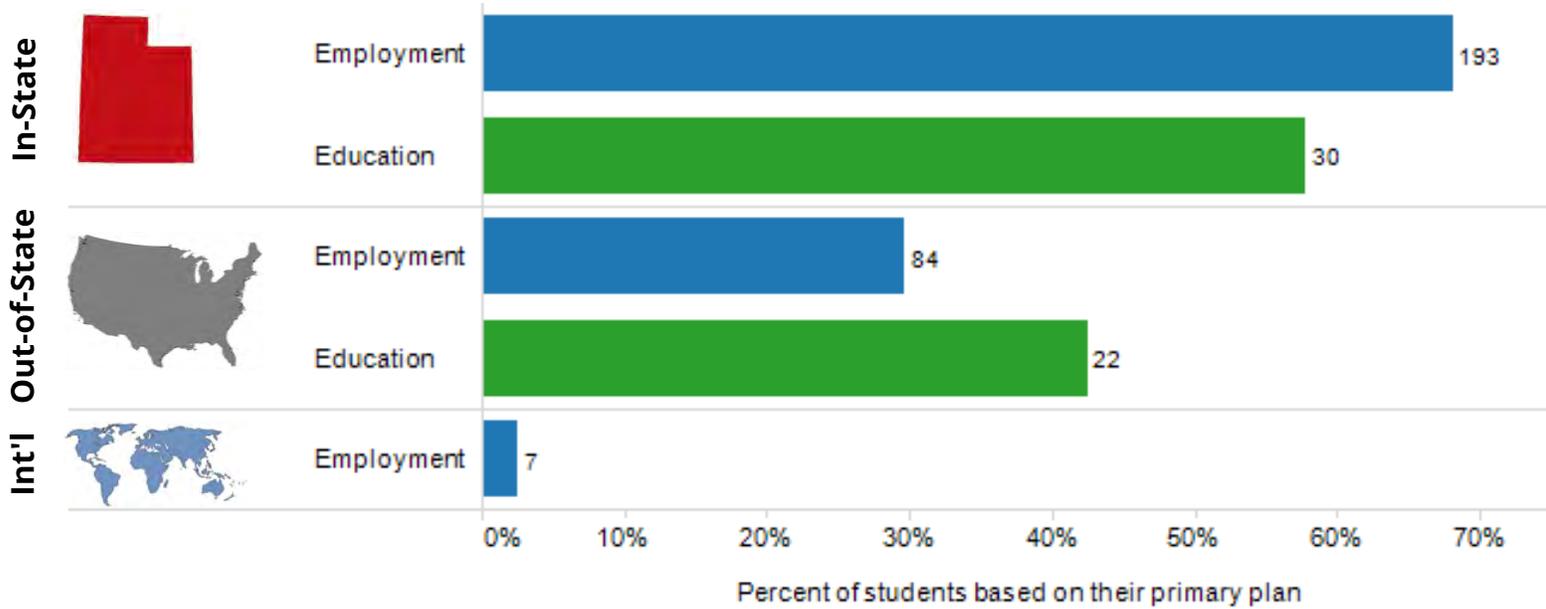
kdries@sa.utah.edu

801-585-5059

First Destination Data: Aug 2015-May 2016 grads



First Destination Data: Aug 2015-May 2016 grads



Salary Data

Mean Salary (Undergraduate Students)

Mean Salary (Graduate Students)



College of Engineering: **\$61,665.53**
University of Utah: **\$46,601.15**

College of Engineering: **\$77,196.70**
University of Utah: **\$66,986.64**

Note: These averages include only those who reported annual salary or hourly rate for full-time employment.

Top Employers



FLASH TECHNOLOGIES
an intel, micron venture



Edwards Lifesciences



X-3

SPECTRUM ENGINEERS

Internship Data: Aug 2015-May 2016 grads

71% of Engineering respondents reported participating in **at least one internship**.

34% reported participating in **2 or more** internships.

30% of internships resulted in an offer for **full-time employment**.

Internship: *"productive work experience in a field related to your major or career goals"*

To continue the growth of an internship culture on campus, the University Career Services authored guidelines to improve the quality of internships available to students. Using this approval rubric from May 1, 2015 to May 1, 2016, University Career Services vetted **1554 internship positions** for posting in the UCareerPath system, making them available to students from all departments, Colleges, degree levels, and areas of study.

Top Internship Organizations

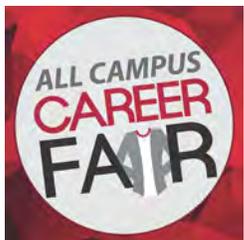
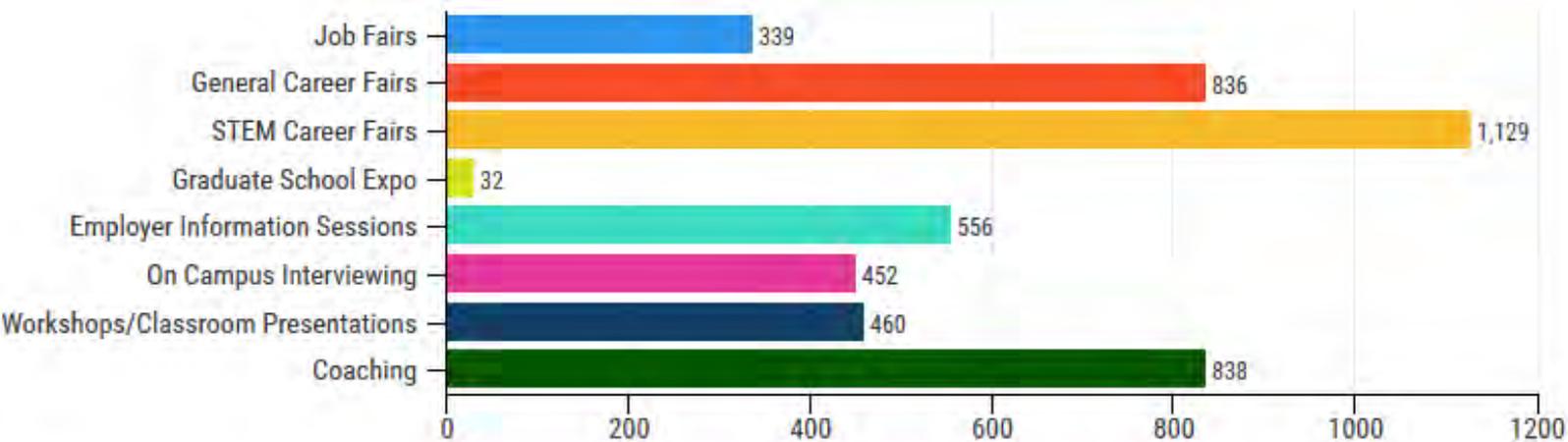
- | | |
|-------------------------------------|---------------------------------|
| University of Utah | BioFire Diagnostics |
| Bard Access Systems | Blackrock
Microsystems |
| L-3 Communications
Systems, West | Goldman Sachs |
| Rocky Mountain
Power | Method Therapeutic
Solutions |
| Northrop Grumman | |
| Spectrum Engineers | |
| SquareHook | |
| Asphalt Zipper | |
| BD Medical | |



Career Services Utilization Data: Jan-Dec 2016

36.7% of Engineering students interacted with Career Services

4614 total student interactions, 1942 unique



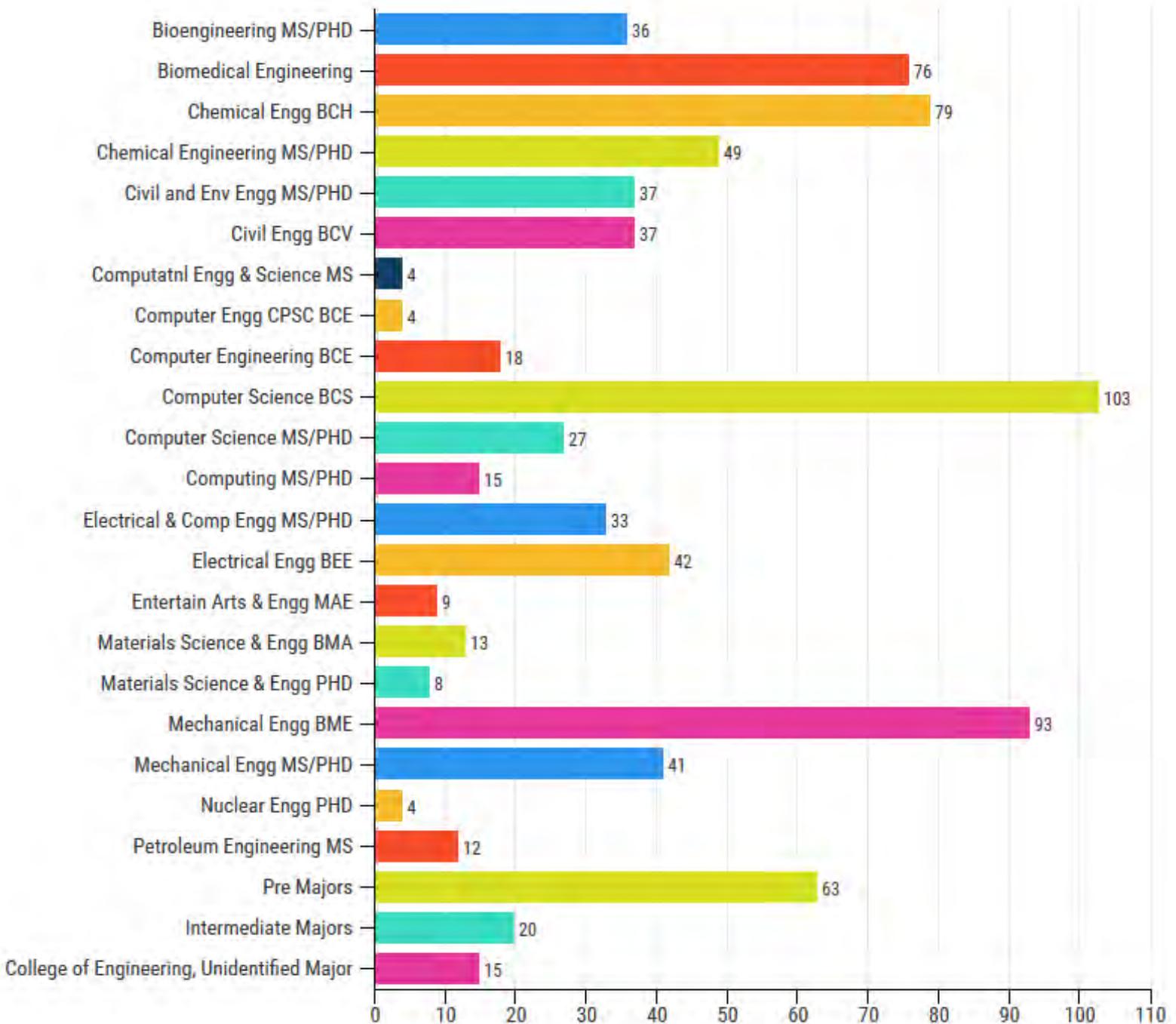
Career Services Utilization Data: Jan-Dec 2016

Student Coaching Data

478 unique student 1:1 coaching appointments.

34% of students who visit Career Services come back for 2+ appointments.

838 Total Appointments by Major



College of Engineering Additional Highlights

2016 Faculty Recognition Award Winners



Dr. Tony Butterfield
Chemical Engineering



Professor Ryan Bown
Entertainment Arts & Engineering



Dr. Joel Harley
Electrical Engineering



Dr. Taylor Sparks
Materials Sciences Engineering



Dr. Ashley Spear
Mechanical Engineering

Testimonials

"Francine has been instrumental towards me getting an internship with eBay in the San Jose area and now a full-time job offer with Microsoft and also the final on-site interview at Google later this month. I owe it all to her."

"The most helpful part of my appointment was getting lots of important information on how to make my LinkedIn page more professional."

"I received word this week that I was selected as a recipient of the 2016 NSF Graduate Research Fellowship! I wanted to thank you for the revisions to my statements last year that help tremendously to strengthen my application."

"I teach for the University and used the Career Services office for help/ guest speaking in my classes on interviewing. Your employees and interns are excellent! They have helped my students with resumes and interview prep repeatedly and with much success."

"[My Career Coach] boosted my confidence and better prepared me for upcoming interviews."

"My interview this morning at Dyno Nobel was excellent! It was surprisingly casual and cordial. I am very glad we met earlier this week, much of what we discussed was directly a part of the interview. Thank you very much for your help. I think I made a very strong impression, and I think it's largely because I was ready with stories."

Opportunities for Greater Collaboration & Synergy

How you can help:

- Systematize process for your college's graduates to complete the institutional First Destination Form.

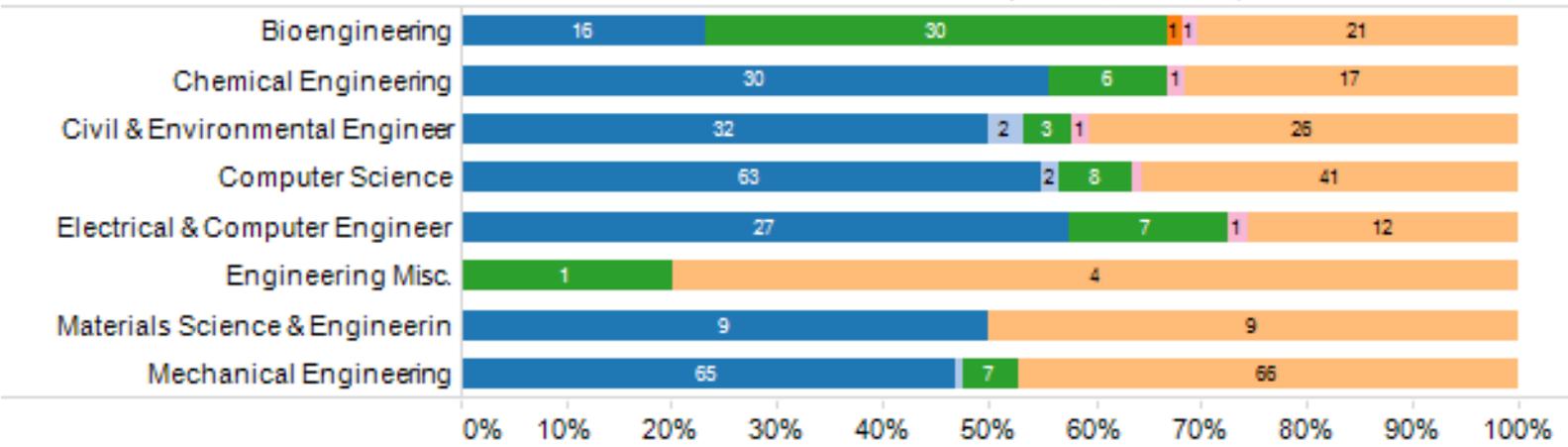
The University has streamlined its process for collecting First Destination data & utilizes a central form which is sent to all graduating students prior to the end of each semester. Please use existing means (exit interviews with students, final communications around graduation requirements, etc.) to ensure your students are completing this form. The link for this form is <http://baseline.campuslabs.com/uou/firstdestinationform> and our ideal time for data collection is between 3 weeks prior to graduation and 4 weeks after graduation.

- Help connect Career Services office and resources to faculty and students.

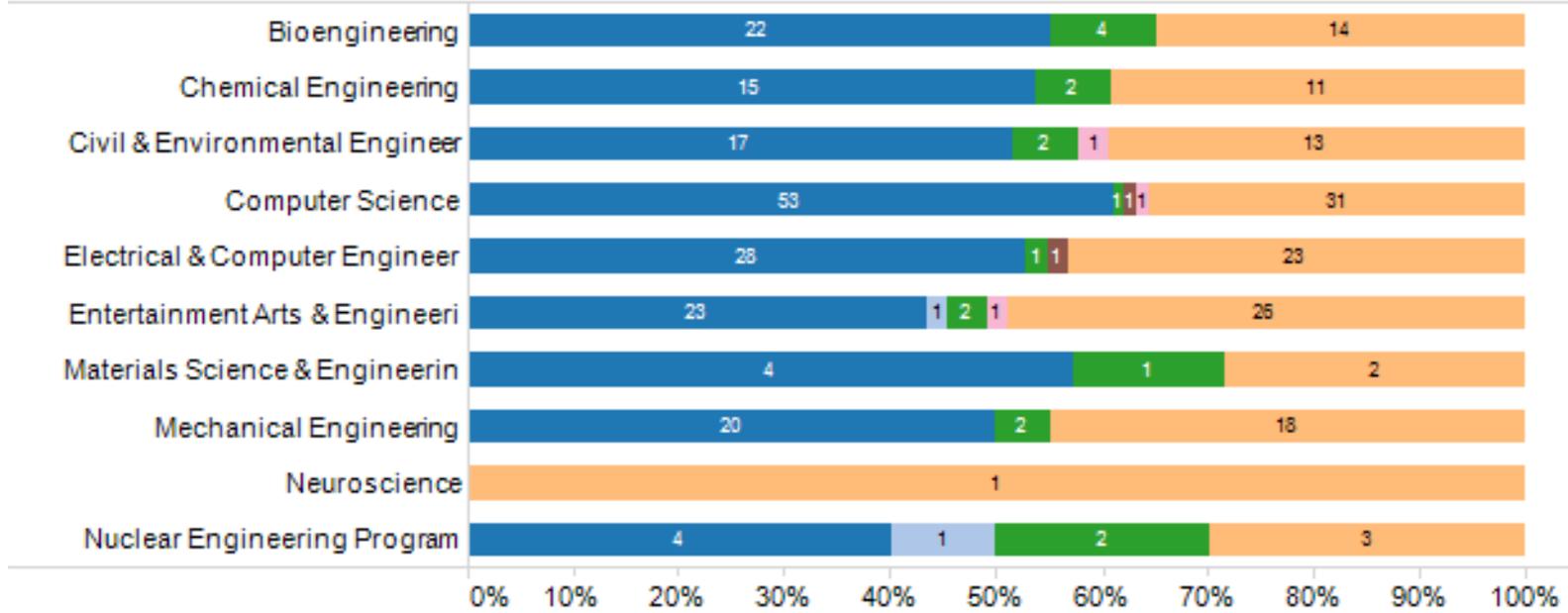
What are the priorities for your College?

Appendix: First Destination Data by majors (Aug 2015-May 2016 grads)

What are the students' First Destination Plans? (Undergraduates)



What are the students' First Destination Plans? (Graduates)

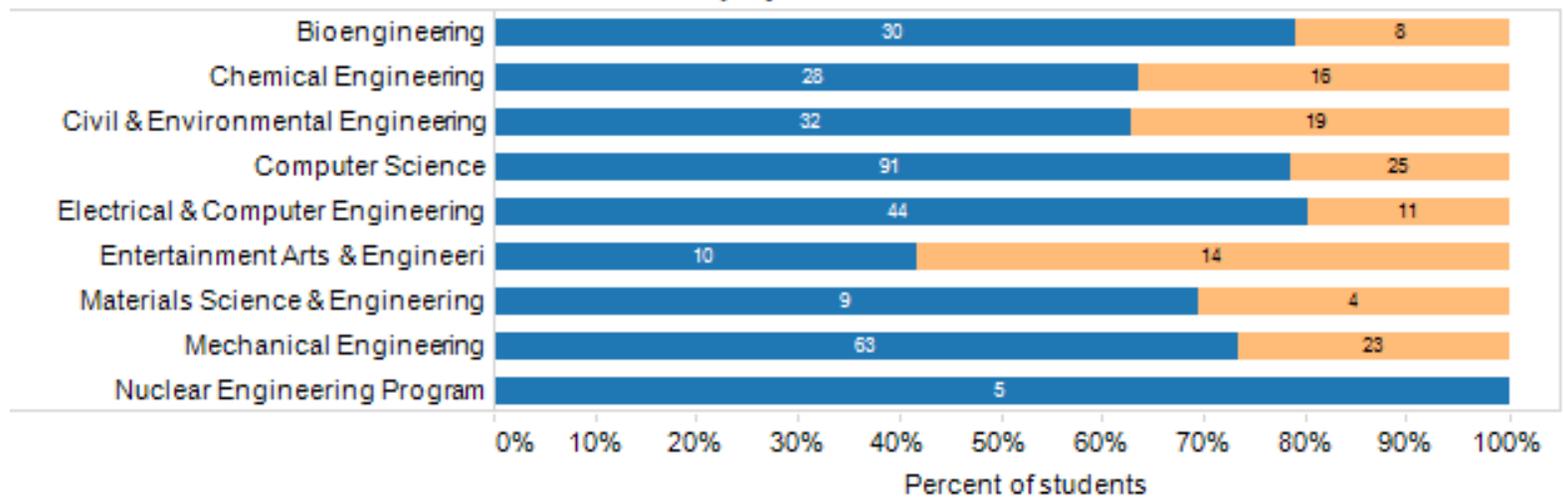


First Destination Plan

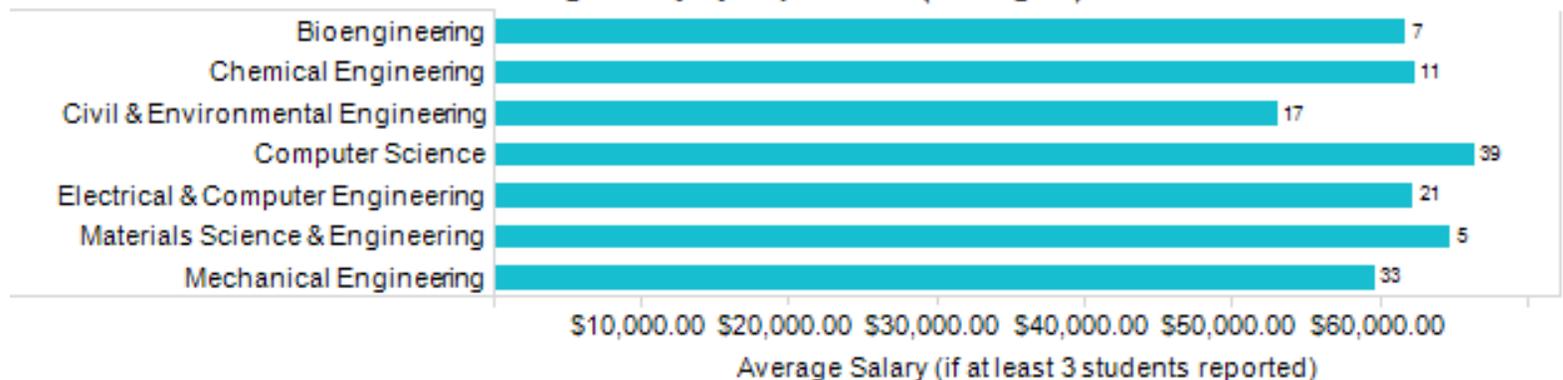
- Employment full-time
- Employment part-time
- Education
- Volunteer or Service Program
- Other
- Unknown

Appendix: First Destination Data by majors (Aug 2015-May 2016 grads)

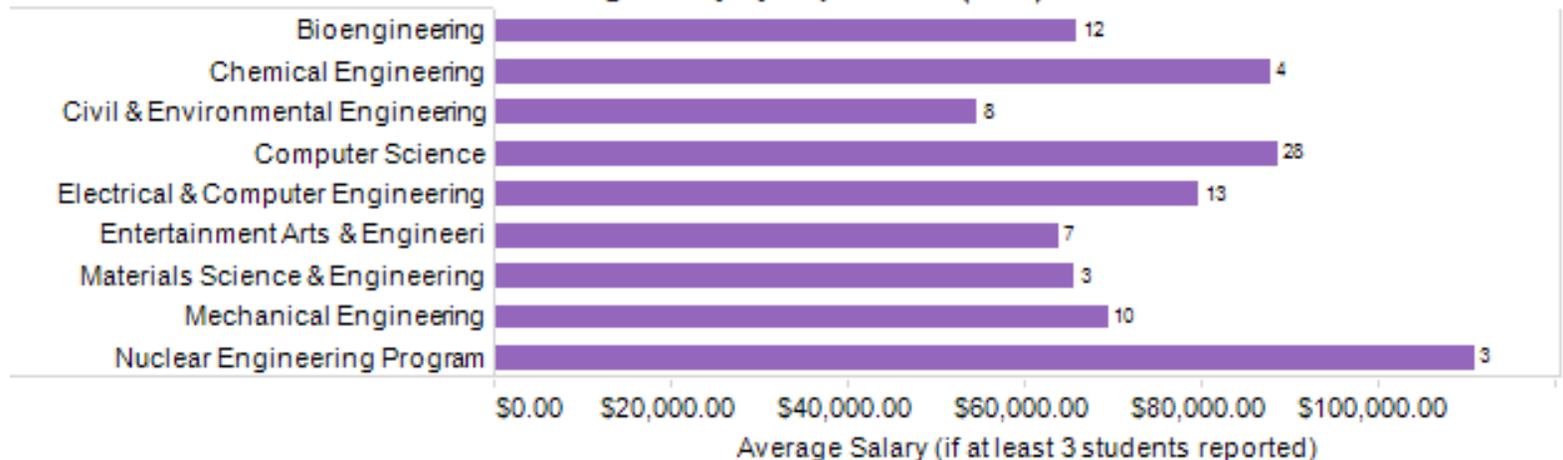
Placement Rates for Employment: **Hired** or **Not Yet Hired**



Average Salary by Department (Undergrad)



Average Salary by Department (Grad)



Labels at the end of each bar indicate how many students (employed full-time) reported income as either an hourly or yearly/salary rate.