CRITERION 3. STUDENT OUTCOMES

3.A Student Outcomes

There are 13 student outcomes for the B.S. degree in the ME program at the University of Iowa. The student outcomes (a) through (k) were repeated verbatim as stated in the Section "General Criteria for Baccalaureate Level Programs" of the ABET Criteria for Accrediting Engineering Programs. For criteria that are specific to the ME program, the program's faculty discussed and unanimously adopted two additional outcomes, i.e., (l) and (m). These outcomes are published on MIE's departmental website.

Outcome (a): an ability to apply knowledge of mathematics, science, and engineering.

Outcome (b): an ability to design and conduct experiments, as well as to analyze and interpret data.

Outcome (c): an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.

Outcome (d): an ability to function on multidisciplinary teams.

Outcome (e): an ability to identify, formulate, and solve engineering problems.

Outcome (f): an understanding of professional and ethical responsibility.

Outcome (g): an ability to communicate effectively.

Outcome (h): the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.

Outcome (i): a recognition of the need for, and an ability to engage in life-long learning.

Outcome (j): a knowledge of contemporary issues.

Outcome (k): an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Outcome (l): an ability to work professionally in either thermal or fluid systems engineering, including the design and realization of such systems.

Outcome (m): an ability to work professionally in mechanical systems engineering, including the design and realization of such systems.

3.B Relationship of Student Outcomes to Program Educational Objectives

Table 3.1 presents the relationship between the student outcomes and the program educational objectives. The relationship was first discussed by the ME ABET committee and then presented to ME faculty members for discussion and approval.

Table 3.1. Relationship between the Student Outcomes and the Program Educational Objectives with a Scale of (1, 2, 3) = (Slightly, Moderate, Strong) Relationship

Program Educational Objectives	Student Outcomes												
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)
1. Will have successful careers in engineering and beyond and will have assumed professional roles of increasing responsibility and impact.	3	3	3	3	3	3	3	3	3	3	3	3	3
2. Will have acquired new knowledge and expertise through professional development opportunities or advanced education.	2	2	2	2	2	1	2	2	3	2	2	2	2
3. Will be engaged in workplace, professional, and civic communities.	1	1	1	3	1	2	3	3	1	2	1	1	1

CRITERION 4. CONTINUOUS IMPROVEMENT

4.A Student Outcomes

Based on the feedback from the 2008-2009 ABET review of the ME Program, the ME faculty decided to use rubrics as the primary assessment tool for each student outcome. A rubric describes a set of performance indicators and their degrees of achievement to facilitate a means of evaluating student outcome. It also contains quantitative elements that allow the instructor to evaluate the extent to which the student has met the expectations, as outlined in the rubric. During the academic year (AY) 2009-2010, the ME faculty designed rubrics and assessment instruments for each student outcome. Several faculty meetings were held to discuss the rubrics and instruments. The rubrics were implemented in AY 2010-2011. The assessment results and corresponding continuous improvement actions based on the rubrics are discussed by the ME faculty each semester. Please refer to the documented minutes of faculty meetings. The following subsections provide details on the assessment process, the frequency of the assessments, the expected level of attainment, and summary and analysis of the assessment results for each student outcome.

4.A.1 Outcome (a): an ability to apply knowledge of mathematics, science, and engineering

(1) <u>Assessment Process</u>

<u>Rubric used for Assessment</u>: Table 4.1 presents the rubric used for assessing outcome (a). The rubric utilizes three performance indicators that examine students' abilities to (1) apply fundamental principles of science and engineering to solve basic problems; (2) apply engineering and mathematical models to solve open-ended problems; and (3) apply advanced mathematical principles to solve problems. Four degrees of achievement, i.e., unsatisfactory (0), marginal (1), satisfactory (2), and exemplary (3) are specified, where the parenthetical values represent the associated numerical scores.

<u>Course used for Assessment</u>: ME:3045 (58:045) Heat Transfer (three credit hours)

ME3045 (58:045), 'Heat Transfer' is a required course offered in the spring semester of the junior year. The application of mathematics in this course is representative of the highest level expected of students in the ME program and includes multi-variate calculus and differential equations. Students must also apply fundamental principles of physics (e.g., conservation laws and heat transfer rate equations) as well as engineering models (e.g., heat transfer correlations) to solve problems. Students' abilities to apply their knowledge of mathematics, science, and engineering are evaluated in homework and exam problems and in an open-ended design project, which each student completes individually.

Table 4.1. Rubric for Outcome (a)

Performance Indicator	Degree of Achievement			
	Unsatisfactory (0)	**Marginal (1)**	**Satisfactory (2)**	**Exemplary (3)**
1. Application of fundamental principles of science and engineering	Cannot identify or write appropriate conservation or rate equation(s), or apply appropriate dimensionless parameters or heat transfer correlations.	Is able to write appropriate equations and parameter definitions but does not exhibit a clear comprehension of how to use them to solve the problem.	Is able to write relevant equations, uses dimensionless parameters properly, and displays a general understanding of how to use to solve the problem, but with some omissions, minor misconceptions, or calculation errors.	Can correctly write and use applicable equations and parameters to correctly and concisely solve the problem.
2. Use of engineering and mathematical models to solve open-ended problems	Cannot identify relevant physical process(es) occurring in a given open-ended problem; cannot propose and justify the use of a particular model(s) to describe the process(es).	Identifies the relevant physical processes, and selects models that describe these processes but does not use them properly to solve the problem.	Identifies the relevant physical processes, selects models that are appropriate for the problem, and uses them correctly (possibly with minor calculation errors).	Identifies the relevant physical processes, selects models that are appropriate for the problem, justifying why they are the best choice of those available, uses them correctly, and clearly explains the limitations of the model for the given problem.
3. Application of advanced mathematical principles to solve Problems	Does not recognize the type of mathematical equation to be solved.	Correctly identifies the appropriate mathematical method to be employed, but cannot effectively select or set up the appropriate mathematical equation.	Correctly identifies the appropriate mathematical model and solves with minor errors or omissions. Uses the solution to provide an answer to the problem.	Correctly identifies the appropriate mathematical model, solves correctly and completely, and uses the solution to provide an answer to the problem.

<u>Assessment Instruments</u>: Table 4.2 describes the assessment instruments pertaining to each performance indicator defined in the rubric of outcome (a).

Table 4.2. Assessment Instruments for Outcome (a)

Performance Indicator	Assessment Instrument
1. Application of fundamental principles of science and	*Examination questions:* Students will be given a problem similar to those in the textbook. The problem will have idealized geometry, boundary conditions, and properties, such that the models discussed in the course will perfectly fit the problem. Students will be required to solve the problem by appropriately applying energy conservation, rate

engineering	equations, dimensionless parameters, heat transfer correlations, appropriate solutions to the heat conduction equation, etc., and substituting appropriate values to compute the solution (temperature distribution, heat flux, etc.).
2. Use of engineering and mathematical models to solve open-ended problems	*Term projects*: The term project is an open-ended design problem in which students will encounter geometries and boundary conditions which do not conform exactly to the idealized cases studied in class. Students work individually and are required to make judgments about the relevant processes to model and the appropriate models to use. Assessment will address the appropriate and accurate use of mathematical and engineering models, as well as the student's justification of the use of the selected models and their understanding of the applicability of the selected model to the problem.
3. Application of advanced mathematical principles to solve problems	*Examination questions*: Students will be tested on their ability to set up and solve advanced mathematical equations to solve a problem. Likely examples involve the heat equation (e.g., selection of the appropriate form, simplification, solution, application of appropriate boundary conditions) or integration of spectral or directional surface properties over a specified range of wavelengths or solid angle.

(2) Frequency of Assessment

Outcome (a) is assessed once per year (every spring semester).

(3) Expected Level of Attainment

The ME Program faculty consider that outcome (a) is attained if the following two dimensions of the performance measure are met for each performance indicator: (1) the average numerical score ≥ 2 and (2) at least 84% of the students have obtained a score ≥ 2. A numerical score equal to two indicates satisfactory performance. The threshold value of 84% is calculated based on the probability, $P[Z \leq 1] = 0.84$, where Z follows the standard normal distribution.

(4) Summary of Evaluation Results and Extent of Outcome Attainment

Table 4.3 presents the assessment results for outcome (a) in terms of both the average scores and percentages of students with scores equal to or greater than 2. The results are broken down for each performance indicator, as described in Table 4.1, and the outcome is assessed for each semester. The numerical results indicate the following:

(i) Both dimensions of the performance measure were mostly met for the first two performance indicators, "*application of fundamental principles of science and engineering*" and "*use of engineering and mathematical models to solve open-ended problems,*" in the spring semesters of 2011, 2012, 2013, and 2014.

(ii) The average scores and percentages of students with scores ≥ 2 for the third performance indicator, "*application of advanced mathematical principles to solve problems,*" were 1.8 and 77.8%, respectively, in the spring of 2011 and 1.3 and 45.7%, respectively, in the spring of 2012. They were significantly lower than the respective target thresholds of 2 and 84% in the spring of 2012. After taking corrective actions in the springs of 2013 and 2014, the re-assessment of the third performance indicator showed a great improvement from 45.7% in the spring 2012 to 74.1% and 92.7% in the springs of 2013 and 2014, respectively. Thus, both dimensions of the performance measure were met for all performance indicators.

Continuous improvements and action plans are described in Section 4.B.1.1.

Table 4.3. Assessment Results for Outcome (a)

Semester	Course Number	Performance Indicator			
		Application of fundamental principles of science and engineering	Use of engineering and mathematical models to solve open-ended problems	Application of advanced mathematical principles to solve problems	Average
(a) Average scores					
Spring 2011	ME3045	2.2	2	1.8	2
Spring 2012	ME3045	2.4	2.4	1.3	2
Spring 2013	ME3045	2.1	2.7	2.0	2.3
Spring 2014	ME3045	2.4	2.6	2.0	2.3
(b) Percentages of scores exceeding 2					
Spring 2011	ME3045	79.4	88.9	77.8	60.3
Spring 2012	ME3045	84	98.8	45.7	67.9
Spring 2013	ME3045	87.1	92.9	74.1	82.4
Spring 2014	ME3045	90.2	93.5	92.7	90.2

4.A.2 Outcome (b): an ability to design and conduct experiments, as well as to analyze and interpret data

(1) Assessment Process

Rubric used for Assessment: Table 4.4 presents the rubric used for assessing outcome (b). The rubric utilizes six performance indicators that examine students' abilities related to (1) laboratory safety; (2) instrumentation usage; (3) experimental procedures; (4) error analysis; (5) data analysis; and (6) experimental design. Four degrees of achievement, i.e., unsatisfactory (0), marginal (1), satisfactory (2), and exemplary (3) are specified, with the the parenthetical values representing the associated numerical scores.

Course used for Assessment: ME:4080 (58:080), 'Experimental Engineering' (four credit hours).

ME:4080 (58:080), 'Experimental Engineering,' covers instrumentation and sensors, calibration, data acquisition, data reduction, error analysis, and overall experimental design. Error analysis includes identification of elemental errors, evaluation of precision and bias errors, instrument dynamic errors, and error propagation. The course is well suited to assess the ability of students to design and conduct experiments and to analyze and interpret experimental results.

Table 4.4. Rubric for Outcome (b)

Performance Indicator	Degree of Achievement: Unsatisfactory (0)	Marginal (1)	Satisfactory (2)	Exemplary (3)
1. Laboratory safety	No appreciation of safety guidelines.	Unsafe lab procedures frequent.	Unsafe lab procedures infrequent.	Observes good lab safety procedures.
2. Instrumentation usage	Does not understand how the instruments work. Cannot select appropriate instrumentation to perform measurements. Is unable to operate the instrumentation provided.	Has minimal understanding of how instruments operate. Needs significant supervision to select the proper equipment and instruments and to operate equipment.	Has mostly a basic understanding of how instruments operate. Needs some guidance to select the proper equipment and instruments and to operate equipment.	Has an understanding of how instruments operate. Can select the proper equipment and instruments and is able to properly operate equipment.
3. Experimental procedures	Cannot follow experimental procedures. Unable to formulate a logic experimental plan. Data documentation is poor leading to loss of data.	Has problems following the logic of the procedures in pre-set experiments. Requires significant supervision to develop and implement experimental procedures. Is aware of standards of data collection and documentation, but has problems following them.	Mostly understands the logic of the procedures in pre-set experiments. With guidance, is able to develop and implement experimental procedures. Follows standards of data collection and documentation, although occasional oversight can cause loss of efficiency or data.	Understands the logic of the procedures in pre-set experiments. Improves on what is suggested. Is able to develop and implement sound experimental procedures. Follows good standards of data collection and documentation.
4. Error analysis	Is unaware of the importance of error analysis. Cannot compute errors.	Is aware of measurement errors but has problem applying the theory and requires significant help to achieve a final result.	Is aware of measurement errors and can estimate most but requires some help to achieve a final result.	Defines and estimates elemental errors. Produces proper statistical estimates of precision errors and evaluation of bias errors and propagates to final result.
5. Data analysis	Cannot relate data to theory.	Attempts analysis of the data but does so with considerable errors.	Most of the time analyzes the data correctly but does not have grasp of the underlying theory. Misses results that are not included in the write-ups.	Uses appropriate theory to analyze the data and extract information from it. Identifies features in the results that are of interest or that deviate from the theory or expected outcome.
6. Experiment design	Unable to design an experiment.	Needs considerable guidance and supervision to design an experiment. Has problems obtaining good data and meaningful results.	Can mostly design adequate experiments. Chooses instrumentation, designs procedures, acquires data, performs analysis and obtains meaningful results with some help.	Able to design an experiment that will produce the desired outcome. Can choose instrumentation, design procedures, acquire the data, perform analysis and obtain meaningful results without help.

<u>Assessment Instruments</u>: Table 4.5 describes the assessment instruments pertaining to each performance indicator defined in the rubric of outcome (b).

Table 4.5. Assessment Instruments for Outcome (b)

Performance Indicator	Assessment Instrument
1. Laboratory safety	Laboratory observation throughout the semester (graded daily by TAs). Lab safety guidelines are provided in the course syllabus and one lecture on lab safety is given at the beginning of the semester.
2. Instrumentation usage	Individual log book and Exam II.
3. Experimental procedures	"Experimental considerations" section in Individual Technical Report (ITR).
4. Error analysis	Exam I and "Error Analysis" section in ITR.
5. Data analysis	"Results and discussion" section in Individual Technical Report.
6. Experiment design	Individual lab logbook in Independent Group Project. In the log book, the selection of instrumentation, design of lab procedures, data acquisition and analysis are used to assess "Experiment Design."

(2) <u>Frequency of Assessment</u>

Outcome (b) is assessed twice per year (fall and spring semesters).

(3) <u>Expected Level of Attainment</u>

The ME Program faculty consider that outcome (b) is attained if the following two dimensions of the performance measure are met for each performance indicator: (1) the average numerical score ≥ 2 and (2) at least 84% of the students have obtained a score ≥ 2. A numerical score equal to two indicates satisfactory performance. The threshold value of 84% is calculated based on the probability, $P[Z \leq 1] = 0.84$, where Z follows the standard normal distribution.

(4) <u>Summary of Evaluation Results and Extent of Outcome Attainment</u>

Table 4.6 presents the assessment results for outcome (b) in terms of both the average scores and percentages of students with scores equal to or greater than 2. The results are broken down for each performance indicator, as described in Table 4.44.4, and the outcome is assessed for each semester. The numerical results indicated the following:

(i) The average scores for all six performance indicators, obtained from 2010 to 2014, were mostly greater than 2 except for the indicators, *"instrumentation usage"* in the spring of 2012 (1.9) and *"error analysis"* in the fall of 2010 (1.8). The scores improved after the fall of 2012, when part of the contents previously taught in ME:4080 (58:080), 'Experimental Engineering,' were moved to the new course ME:3351 (58:051), 'Engineering Instrumentation.' Overall, based on the first dimension of the performance measure, outcome (b) was achieved.

(ii) The percentages of students with scores ≥ 2 for some performance indicators were below the target value of 84%. Corrective actions undertaken in the fall semester of

2012 yielded significantly better results where improvements were required. Even so, the percentage scores for the indicators *"experimental procedures"* and *"experiment design"* were still below 84% in the fall of 2012. After taking corrective action in the spring of 2013, the re-assessment of the two indicators showed improvement in the percentage scores. Thus, both dimensions of the performance measure were met for all performance indicators in the fall semester of 2013 and the spring semester of 2014.

Continuous improvement actions are described in Section 4.B.1.2.

Table 4.6. Assessment Results for Outcome (b)

Semester	Course Number	Performance Indicator						
		Lab safety	Instrum. usage	Exp. proced.	Error analysis	Data analysis	Exp. design	Average
(a) Average scores								
Fall 2010	ME:4080	2.7	2.2	2.1	1.8	2.5	2.2	2.3
Spring 2011	ME:4080	3	2.1	2.5	2.1	2.6	2.7	2.5
Fall 2011	ME:4080	3	2.1	2.4	2.7	2.5	2.9	2.6
Spring 2012	ME:4080	3	1.9	2.8	2.7	2	2.3	2.5
Fall 2012	ME:4080	3	2.6	2.3	2.8	2.4	2.4	2.6
Spring 2013	ME:4080	2.9	2.6	2.6	2.7	2.0	2.3	2.5
Fall 2013	ME:4080	2.6	2.4	2.9	2.6	2.3	2.6	2.5
Spring 2014	ME:4080	2.9	2.4	2.5	2.7	2.3	2.9	2.6
(b) Percentages of scores exceeding 2								
Fall 2010	ME:4080	100	73.3	60	46.7	93.3	86.7	86.7
Spring 2011	ME:4080	100	73.3	95	75.0	96.7	96.7	88.3
Fall 2011	ME:4080	100	91.7	91.7	100	100	100	91.7
Spring 2012	ME:4080	100	72.9	97.9	100	83.3	83.3	93.8
Fall 2012	ME:4080	100	100	80	100	100	70	100
Spring 2013	ME:4080	98.5	91.0	92.5	98.5	89.6	86.6	92.5
Fall 2013	ME:4080	93.3	86.7	100.0	93.3	86.7	86.7	93.3
Spring 2014	ME:4080	98.5	95.6	85.3	95.6	85.3	98.5	94.1

4.A.3 Outcome (c): an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

(1) Assessment Process

Rubric used for Assessment: Table 4.7 presents the rubric used for assessing outcome (c). The rubric utilizes four performance indicators that examine students' abilities related to (1) goals and objectives; (2) resources, issues, and constraints; (3) design solution and process implementation; and (4) demonstration of design skills and design innovation. Four degrees of achievement, i.e., unsatisfactory (0), marginal (1), satisfactory (2), and exemplary (3) are specified, with the parenthetical values representing the associated numerical scores.

Courses used for Assessment: ME:4086 (58:086), 'Mechanical Engineering Design Project'

(three credit hours) and ME:4186 (58:186), 'Enhanced Design Experience' (three credit hours).

ME:4086 (58:086) is a required capstone design course, and ME:4186 (58:186) is a required design course for the Design EFA and both are offered during the senior year. A common principal goal of these courses is to integrate engineering and science coursework by developing an ability to design a system, component, or process to meet desired needs within realistic constraints, such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability. The capstone design course is well suited to assess student outcome (c).

Table 4.7 Rubric for Outcome (c)

Performance Indicator	Degree of Achievement			
	Unsatisfactory (0)	Marginal (1)	Satisfactory (2)	Exemplary (3)
1. Goals and objectives	No understanding of design goals or objectives; objectives are absent or poorly formulated.	Has some understanding of objectives but unclear about the 'big picture;' has formulated some design objectives.	Recognizes goals and shows understanding of these to design objectives; narrow focus on design.	Demonstrates understanding of overall goals; knows that the design may be a subset of a larger system design.
2. Resources, issues, and constraints	Unaware of design issues and constraints, including economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability; no resources identified.	Has some understanding of design issues and constraints and has addressed resources.	Well-documented design issues and constraints; has addressed resources needed to complete design or system.	In addition to (2), has developed alternative plans for resources; has alternative methods of meeting design issues and constraints.
3. Design solution and process implementation	Tasks identified, but no evidence of progression from one task to the next; time critical tasks or schedule not identified; implementation of process ignored.	Tasks identified and progression is listed; demonstrates some understanding of time-sensitive tasks; has considered how to address these tasks; process follows a specified plan and orderly implementation.	Well defined progression; critical tasks identified and methods to address them are adequate; process development follows defined tasks and meets schedule.	Has worked out a systematic and detailed list of tasks with logical schedule; attention is paid to time critical tasks; has provided schedule for time critical tasks; detailed schedule according to plan is provided.
4. Demonstration of design skills and design innovation	Progress is almost non-existent; no skills shown and concept of innovation is non-existent.	Progress is adequate and shows design skills; hardly any design innovation; limited variations.	Good progress with good design skills; limited design innovation; alternatives considered.	Progress according to schedule; good design skills; design has many innovations and alternatives.

Assessment Instruments: Table 4.8 describes the assessment instruments pertaining to each performance indicator defined in the rubric of outcome (c).

Table 4.8. Assessment Instruments for Outcome (c)

Performance Indicator	Assessment Instrument			
	Design Review Meetings	**Project Proposal**	**Final Team Presentation**	**Final Team Report**
1. Goals and objectives	Student performance when chairing review meetings	*Goals and Objectives* section	Student performance describing project objectives	*Executive Summary* and *Introduction* section describing goals and objectives
2. Resources, issues, and constraints	Student performance when chairing review meetings	*Resources and Constraints* section	Student performance describing use of resources and constraints	*Procedure* section describing resources, issues, and constraints
3. Design solution and process implementation	Student performance when chairing review meetings	*Expected Results and Outcomes* section	Student performance discussing design decisions	*Results and Discussion* section describing design solution and process implementation
4. Demonstration of design skills and design innovation	Student performance when chairing review meetings	*Expected Results and Outcomes* section	Student performance describing effectiveness of design solutions	*Results and Discussion* and *Conclusion* sections describing design skills and innovation

(2) <u>Frequency of Assessment</u>

Outcome (c) is assessed twice per year (fall and spring semesters).

(3) <u>Expected Level of Attainment</u>

The ME Program faculty consider that outcome (c) is attained if the following two dimensions of the performance measure are met for each performance indicator: (1) the average numerical score ≥ 2 and (2) at least 84% of the students have obtained a score ≥ 2. A numerical score equal to two indicates satisfactory performance. The threshold value of 84% is calculated based on the probability, $P[Z \leq 1] = 0.84$, where Z follows the standard normal distribution.

(4) <u>Summary of Evaluation Results and Extent of Outcome Attainment</u>

Table 4.9 presents the assessment results for outcome (c) in terms of both the average scores and percentages of students with scores equal to or greater than 2. The results are broken down for each performance indicator, as described in Table 4.7, and the outcome is assessed for each semester. The numerical results indicate the following:

(i) Both dimensions of the performance measure assessed via ME:4086 (58:086) were met for all four performance indicators in the fall semester of 2010, the spring and fall semesters of 2012 and 2013, and the spring semester of 2014. The data for the fall and spring semesters of 2011 were not collected and this outcome could not be assessed for those semesters. Based on the available data from 2010 and 2012-2014, outcome (c) was achieved.

(ii) Beginning in the spring of 2013, ME:4186 (58:186) and ME:4086 (58:086) were used for the assessment of outcome (c). Both dimensions of the performance measure based on ME:4186 (58:186) data were met for all performance indicators.

Continuous improvements and action plans are described in Section 4.B.1.3.

Table 4.9. Assessment Results for Outcome (c)

Semester	Course Number	Performance Indicator				
		Goals and objectives	**Resources, issues, and constraints**	**Design solution and process implementation**	**Demonstration of design skills and design innovation**	**Average**
(a) Average scores						
Fall 2010	ME:4086	2.8	2.8	2.8	2.8	2.8
Spring 2011	ME:4086	NA	NA	NA	NA	NA
Fall 2011	ME:4086	NA	NA	NA	NA	NA
Spring 2012	ME:4086	2.7	2.6	2.6	2.6	2.6
Fall 2012	ME:4086	2.8	2.7	2.7	2.7	2.7
Spring 2013	ME:4086	2.8	2.7	2.5	2.2	2.6
Spring 2013	ME:4186	2.6	2.6	2.6	2.6	2.6
Fall 2013	ME:4086	2.7	2.5	2.6	2.5	2.6
Spring 2014	ME:4086	2.6	2.4	2.5	2.3	2.6
Spring 2014	ME:4186	2.7	2.7	2.6	2.7	2.7
(b) Percentages of scores exceeding 2						
Fall 2010	ME:4086	100	100	100.0	100	100
Spring 2011	ME:4086	NA	NA	NA	NA	NA
Fall 2011	ME:4086	NA	NA	NA	NA	NA
Spring 2012	ME:4086	100	100	96.3	100	100
Fall 2012	ME:4086	100	100	100	100	100
Spring 2013	ME:4086	100	100	100	90	100
Spring 2013	ME:4186	100	100	100	100	100
Fall 2013	ME:4086	100	100	100	100	100
Spring 2014	ME:4086	100	100	100	84	100
Spring 2014	ME:4186	100	91.7	91.7	100	91.7

4.A.4 Outcome (d): an ability to function on multidisciplinary teams

(1) <u>Assessment Process</u>

Rubric used for Assessment: Table 4.10 presents the rubric used for assessing outcome (d). The rubric utilizes five performance indicators that examine students' abilities related to (1) initiative; (2) responsibility; (3) contribution to team work or project; (4) multi-disciplinary interaction; and (5) intra-team communication skills. Four degrees of achievement, i.e., unsatisfactory (0), marginal (1), satisfactory (2), and exemplary (3) are specified for which the parenthetical values represent the associated numerical scores.

Courses used for Assessment: ME:4086 (58:086), ‘Mechanical Engineering Design Project’ (three credit hours); ME:4186 (58:186), ‘Enhanced Design Experience’ (three credit hours); and ENGR:2760 (57:021), ‘Design for Manufacturing’ (three credit hours)

ME:4086 (58:086) is a required capstone design course, and ME:4186 (58:186) is a required design course for the Design EFA; both are offered during the senior year. The goals of these courses are to integrate engineering and science coursework, while concurrently developing written communication, oral communication, and multi-disciplinary teamwork skills. This integration is accomplished by having the students work on a design project, which is technically sound, raises awareness of contemporary issues, and develops appreciation of the economic, global, societal and ethical contexts of engineering work. These courses were found to be well-suited for assessing the ability of students to work effectively on multi-disciplinary teams.

ENGR:2760 (57:021) is a required course offered during the sophomore year. The course requires student teams to follow a formal design process and manufacture and test the product they develop against the products of other student groups. This course includes this activity to help the students learn about various manufacturing processes and provide them hands-on experience with the machine tools in the ‘Design for Manufacturing Laboratory’ followed by applying them on a real-world project, e.g., the “Electric Car Project.” Student teams work in the ‘Design for Manufacturing Laboratory’ under the close supervision of the instructor and teaching assistants. The evaluation is performed by a panel consisting of the instructor and the TAs in addition to students’ peer evaluation.

Table 4.10. Rubric for Outcome (d)

Performance Indicator	Degree of achievement			
	Unsatisfactory (0)	Marginal (1)	Satisfactory (2)	Exemplary (3)
1. Initiative	Does not show interest in work. Passive at team meetings. Does not initiate cooperation/ interaction with teammates and/or professionals from other disciplines.	Shows some interest in work. Participates in team meetings, but unable to lead a discussion. Occasionally initiates cooperation with teammates, but unable to be in charge of the project tasks.	Exhibits interest in work as evidenced by in-depth study of assigned tasks and active participation in project discussions. Assumes leadership roles. Initiates cooperation with teammates and professionals from other disciplines.	Generates opportunities to enrich project outcomes, while exhibiting systematic and rigorous approach to work. Leads most of the discussions at team meetings. Recognized as a team leader by the teammates. Effectively engages in collaboration with professionals from other disciplines to benefit the project.
2. Responsibility	Does not do assigned work. Misses team meetings. Ignores deadlines. Lacks personal responsibility. Viewed as unreliable and irresponsible by other teammates.	Does some of the assigned work. Attends team meetings, but often is late or unprepared. Aware of the importance of individual’s responsibility in the team success, but often is reluctant to exercise it.	Performs all assigned work. Acts professionally. Viewed as reliable and responsible by teammates. Has positive impact on team dynamics by ensuring individual and team discipline and accountability.	Performs all assigned work. Acts professionally at all times. Has a strong sense of personal responsibility and expects the same from others. Has a strong impact on team dynamics by fostering individual and team discipline and accountability.
3. Contribution to team work or project	Doesn’t contribute to team project; no useful suggestion to address team’s needs; doesn’t collect any useful information needed for the project or work.	Tries to offer some ideas but not well-thought out or developed; collects information when pushed to do so but often late; contributes little to team’s work or project.	Collects useful, basic information; usually offers good ideas to meet team’s needs	Offers well-developed and clearly expressed ideas to help team in its project; performs all tasks effectively and in a timely manner; goes well beyond expectations to help the team complete the project.
4. Multi-disciplinary interaction	Refuses to engage in dialog with team members from other disciplines; Does not bother to learn even basic vocabulary required to communicate with team members from other disciplines	If pressured, will engage in dialog with team members from other disciplines. Is poorly prepared and spends little time learning basic vocabulary of other disciplines and applies vocabulary with other team members only as a last resort.	Occasionally engages in dialog with team members from other disciplines. Is moderately well prepared and spends some time learning basic vocabulary of other disciplines and applies vocabulary with other team members as needed to accomplish project tasks.	Actively engages in dialog with team members from other disciplines and encourages other team members to do the same. Is well prepared and spends time learning basic and some advanced vocabulary of other disciplines and applies vocabulary with other team members as needed to accomplish project tasks.
5. Intra-team communication skills	Does not talk to other team members. Does not reply to emails or requests for help from other team members.	Is slow to reply to emails. Doesn’t provide needed information to others. Doesn’t request needed materials.	Replies to emails in a reasonable amount of time. Discusses tasks, goals, and provides information as needed.	Is pro-active about identifying information and communicating it to team-members. Helps other to locate information and share among all parties involved.

Assessment Instruments: Table 4.11 describes the assessment instruments pertaining to each performance indicator defined in the rubric of outcome (d).

Table 4.11. Assessment Instruments for Outcome (d)

Performance Indicator	Assessment Instrument			
	Final team report from ME:4086/ME:4186[(a)]	Individual student’s essay from ME:4086 and ME:4186[(a)]	Student peer evaluations from ME:4086 and ME:4186[(a)]	Laboratory observations from ENGR:2760
1. Initiative		Student essay on promoting interaction with	Student peer evaluation forms grading initiative	

		teammates and other professionals	in performing assigned work	
2. Responsibility			Student peer evaluation forms grading responsibility in performing assigned work	Laboratory observations evaluating students' responsibility, including participation in the assigned work
3. Contribution to team work or project			Student peer evaluation forms grading contribution to team work or project	Laboratory observations evaluating students' contribution to team work or project
4. Multi-disciplinary interaction	*Results and Discussion* section explaining interaction with vendors and collaborators and describing effective integration of work from different disciplines	Student essay describing effective integration of work from different disciplines	Student peer evaluation forms grading contribution to multi-disciplinary interaction	Laboratory observations evaluating students' interactions on multi-disciplinary teams
5. Intra-team communication skills			The assessment of this performance indicator is based on 1) idea sharing and exchanging between team members and 2) the support between subtasks	

(a) ME:4086 is used for both fall and spring semesters, whereas ME:4186 is used only for spring semesters.

(2) <u>Frequency of Assessment</u>

Outcome (d) is assessed twice per year.

(3) <u>Expected Level of Attainment</u>

The ME Program faculty consider that outcome (d) is attained if the following two dimensions of the performance measure are met for each performance indicator: (1) the average numerical score ≥ 2 and (2) at least 84% of the students have obtained a score ≥ 2. A numerical score equal to two indicates satisfactory performance. The threshold value of 84% is calculated based on the probability, $P[Z \leq 1] = 0.84$, where Z follows the standard normal distribution.

(4) <u>Summary of Evaluation Results and Extent of Outcome Attainment</u>

Table 4.12 presents the assessment results for outcome (d) in terms of both the average scores and percentages of students with scores equal to or greater than 2. The results are broken down for each performance indicator, as described in Table 4.10, and the outcome is assessed for each semester. The numerical results indicate the following:

(i) Data were not collected in the spring and fall semesters of 2011 or in the spring semester of 2012, and the outcomes were not assessed. With the data collected in fall semester of 2010, the spring and fall semesters of 2012, the spring and fall semesters of 2013, and the spring semester of 2014, both dimensions of the performance measure were mostly met for all performance indicators. The only exception was that, for the third performance indicator, "*contribution to teamwork or project*" in the fall semester of 2012 semester, the score of 80% using ENGR:2760 (57:021) was slightly below the target value of 84%. However, this percentage score was improved to 97.9% in the spring of 2013, but it was 82.6% in the fall of 2013. This can be explained by the very low enrollment of ME students (thus, a small sample of 23) in ENGR:2760 (57:021) in fall semester of 2013. The percentage increased back to 96.9% in the spring of 2014, when there were 96 ME students taking the course. Therefore, outcome (d) was achieved.

(ii) Based on the initial data and faculty discussions, the performance indicators for outcome (d) were amended by replacing "*cooperation*" with "*contribution to team work or project*," and "*knowledge transfer*" was replaced by "*multi-disciplinary interaction*." The revised rubric provides an improved description of outcome (d).

Continuous improvements and action plans are described in Section 4.B.1.4.

Table 4.12. Assessment Results for Outcome (d)

Semester	Course Number	Performance Indicator: Initiative	Responsibility	Contribution to teamwork or project[a]	Multi-disciplinary interaction[b]	Intra-team Communication skills[f]	Average
(a) Average scores							
Fall 2010	ME:4086	2.6	2.7	2.8[c]	2.7[d]		2.7
Spring 2011	ME:4086	NA	NA	NA	NA		NA
Spring 2011	ME:4186	NA	NA	NA	NA		NA
Fall 2011	ME:4086	NA	NA	NA	NA		NA
Spring 2012	ME:4086	2.6	2.6	2.6[c]	2.6[d]		2.6
Spring 2012	ME:4186	NA	NA	NA	NA		NA
Spring 2012	ENGR:2760	_[e]	2.7	2.4	2.7		2.6
Fall 2012	ME:4086	2.6	2.6	2.6[c]	2.6[d]		2.6
Fall 2012	ENGR:2760	_[e]	2.7	2.6	2.6		2.6
Spring 2013	ME:4086	2.7	2.7	2.7	2.7	2.8	2.7
Spring 2013	ME:4186	2.8	2.9	2.9	2.9	2.8	2.9
Spring 2013	ENGR:2760	_[e]	2.7	2.7	2.8		2.7
Fall 2013	ME:4086	2.6	2.8	2.6	2.2	2.9	2.6
Fall 2013	ENGR:2760	_[e]	2.4	2.4	2.5		2.4
Spring 2014	ME:4086	2.6	2.8	2.8	2.6	2.8	2.7
Spring 2014	ME:4186	2.5	2.7	2.8	2.7	2.8	2.7

Spring 2014	ENGR:2760	_[e]	2.8	2.7	2.7		2.7
(b) Percentages of scores exceeding 2							
Fall 2010	ME:4086	94.1	91.2	97.1[c]	97.1[d]		94.1
Spring 2011	ME:4086	NA	NA	NA	NA		NA
Spring 2011	ME:4186	NA	NA	NA	NA		NA
Fall 2011	ME:4086	NA	NA	NA	NA		NA
Spring 2012	ME:4086	96.3	96.3	100[c]	100[d]		96.3
Spring 2012	ME:4186	NA	NA	NA	NA		NA
Spring 2012	ENGR:2760	_[e]	93.8	90.1	98.4		93.8
Fall 2012	ME:4086	92	88	100[c]	96[d]		92
Fall 2012	ENGR:2760	_[e]	85	80	95		95
Spring 2013	ME:4086	93.1	96.6	89.7	96.6	93.1	96.6
Spring 2013	ME:4186	100	100	100	100	100	100
Spring 2013	ENGR:2760	_[e]	98.9	97.9	98.9		98.6
Fall 2013	ME:4086	95.7	91.3	87.0	91.3	95.7	95.7
Fall 2013	ENGR:2760	_[e]	87	82.6	91.3		87
Spring 2014	ME:4086	91.3	95.7	91.3	95.7	95.7	95.7
Spring 2014	ME:4186	87.5	91.7	95.8	100	91.7	91.7
Spring 2014	ENGR:2760	_[e]	97.9	96.9	96.9		97.2

(a) The indicator "Contribution to teamwork or project" is a revised version of the indicator "Cooperation." The revised version was adopted in the spring of 2013.
(b) The indicator "Multi-disciplinary interaction" is a revised version of the indicator "Knowledge transfer." The revised version was adopted in the spring of 2013.
(c) The scores are based on the previously used indicator "Cooperation."
(d) The scores are based on the previously used indicator "Knowledge transfer."
(e) Not assessed.
(f) The indicator "Intra-team communication skills" was added in the spring of 2013.

4.A.5 Outcome (e): an ability to identify, formulate, and solve engineering problems

(1) Assessment Process

Rubric used for Assessment: Table 4.13 presents the rubric used for assessing outcome (e). The rubric utilizes three performance indicators that examine students' abilities related to (1) identifying and formulating an engineering problem; (2) the selection and use of proper engineering solution methods; and (3) the analysis and interpretation of problem solutions. Four degrees of achievement were specified, i.e., unsatisfactory (0), marginal (1), satisfactory (2), and exemplary (3) for which the parenthetical values represent the associated numerical scores.

Course used for Assessment: ME:3052 (58:052), 'Mechanical Systems' (four credit hours)

ME:3052 (58:052) is a required course during the junior year in the Mechanical Engineering Program. The course requires each student to complete a project and prepare a written report. The goal of the project is to develop an engineering solution to an open-ended problem that is described using non-technical language. Students are expected to identify an engineering problem in the project narrative, formulate an appropriate engineering model, and solve this model using appropriate analytical and computational techniques. A written project report is used to assess the rubric criteria. The course has been found to be well-suited to assessing the ability

of students to identify, formulate, and solve engineering problems.

Table 4.13. Rubric for Outcome (e)

Performance Indicator	Degree of Achievement			
	Unsatisfactory (0)	**Marginal (1)**	**Satisfactory (2)**	**Exemplary (3)**
1. Ability to identify and formulate engineering problem	Unable to recognize engineering aspects of the problem. Cannot formulate an engineering model. Lack of technical reasoning; does not use appropriate technical terminology.	Recognizes engineering aspects of the problem at a superficial level. The formulated engineering model has deficiencies. Shaky technical reasoning; occasional use of non-standard or inappropriate terminology.	Recognizes engineering aspects of the problem. Able to generate adequate and correctly formulated engineering models. Solid technical reasoning; good command of terminology.	Recognizes engineering aspects of the problem, their complexity, and relative importance. Formulates clear and precise engineering models and the underlying assumptions. Rigorous and deep technical reasoning.
2. Selection and use of appropriate analytical and computational tools	Lacks knowledge of the necessary engineering methods and tools. The selected methods are inadequate for solving the problem; incorrect use of the solution techniques.	Has some knowledge of the appropriate engineering techniques. The selected methods are adequate, but not utilized to their full capability and/or utilized with some errors.	Has good knowledge of appropriate engineering techniques. The selected tools are adequate and efficient; demonstrates proficiency in using these solution methods.	Has full knowledge and understanding of engineering techniques; applies concurrent methods throughout solution procedures. Meticulous and creative approach to standard solution methods.
3. Analysis and interpretation of the solutions to problems	No solution or only a partial solution is constructed. No analysis of the solution and its engineering feasibility is conducted.	The constructed solution has some weaknesses; its analysis and interpretation are incomplete and may miss important implications of the solution's engineering feasibility.	The constructed solution is technically sound and complete. A detailed analysis of the solution as to its engineering feasibility is conducted, including sensitivity studies and other appropriate considerations	A comprehensive set of solutions that depend on various assumptions or conditions is developed. An in-depth and thorough solution analysis, which determines limits of its applicability, illustrates it on case studies is conducted.

Assessment Instruments: Table 4.14 describes the assessment instruments pertaining to each performance indicator defined in the rubric of outcome (e).

Table 4.14. Assessment Instruments for Outcome (e)

Performance Indicator	Assessment instrument
	Project report
1. Ability to identify and formulate engineering problem	This performance indicator is evaluated using the *Problem formulation* section of the project report. Students are required to identify technical aspects of the problem; to generate and formulate an engineering model; and to provide a clear and concise description of the hypotheses, assumptions, and methodologies to be used to solve the problem.
2. Selection and use of appropriate analytical and computational tools	This performance indicator is evaluated using the *Solution procedure* section of the project report. Students are required to provide a detailed description of the specific analytical and computational methods used to solve the problem. These methods (e.g., elementary beam theory, failure theories, solid modeling, and finite element analysis) are taught in ME:3052, the 'Mechanical Systems' course and other related courses (i.e., 57:019, 'Mechanics of Deformable Bodies' and ENGR:2760, 'Design for Manufacturing').
3. Analysis and interpretation of the solutions to problems	This performance indicator is evaluated using the *Results and Discussion* section of the project report. Students are required to provide detailed analysis of the results they obtained using at least two different solution methods (analytical vs. computational); validate the results; discuss the impact of various hypotheses and assumptions in the problem formulation on the results; discuss limitations of the solution methods and how they impact the results; discuss design implications of the results.

(2) Frequency of Assessment

Outcome (e) is assessed once per year (spring semester).

(3) Expected Level of Attainment

The ME Program faculty consider that outcome (e) is attained if the following two dimensions of the performance measure are met for each performance indicator: (1) the average numerical score ≥ 2 and (2) at least 84% of the students have obtained a score ≥ 2. A numerical score equal to two indicates satisfactory performance. The threshold value of 84% is calculated based on the probability, $P[Z \leq 1] = 0.84$, where Z follows the standard normal distribution.

(4) Summary of Evaluation Results and Extent of Outcome Attainment

Table 4.15 presents the assessment results for outcome (e) in terms of both the average scores and percentages of students with scores equal to or greater than 2. The results are broken down for each performance indicator, as described in Table 4.13, and for each semester the outcome is assessed. The numerical results indicate the following:

(i) The average scores for all three performance indicators, obtained in the spring semesters of 2011, 2012, and 2013, are equal to or greater than 2, thereby satisfying the first dimension of the performance measure.

(ii) However, the percentages of students with scores ≥ 2 for a few performance indicators were slightly less than the target value of 84% in the spring semesters of 2011 and 2012. The corrective actions that were undertaken in the spring of 2013 improved the second dimension of the performance measure. Thus, outcome (e) was achieved.

Continuous improvement actions are described in Section 4.B.1.5.

Table 4.15. Assessment Results for Outcome (e)

Semester	Course Number	Performance Indicator: Ability to identify and formulate engineering problem	Selection and use of appropriate analytical and computational tools	Analysis and interpretation of the solutions to problems	Average
(a) Average scores					
Spring 2011	ME:3052	2	2	2	2
Spring 2012	ME:3052	2.2	2.2	2.2	2.2
Spring 2013	ME:3052	2.7	2.8	2.6	2.7
Spring 2014	ME:3052	2.8	2.9	2.6	2.7
(b) Percentages of scores exceeding 2					
Spring 2011	ME:3052	78.5	90.8	76.9	64.6
Spring 2012	ME:3052	82.6	85.2	76.5	84.6
Spring 2013	ME:3052	100.0	100.0	92.0	98.3
Spring 2014	ME:3052	98.5	98.5	93.8	96.9

4.A.6 Outcome (f): an understanding of professional and ethical responsibility

(1) Assessment Process

Rubric used for Assessment: Tanle 4.16 presents the rubric used for assessing outcome (f). The rubric utilizes three performance indicators that examine students' abilities related to (1) knowledge of the National Society of Professional Engineers' (NSPE's) code of engineering ethics; (2) ethical considerations in engineering practice; and (3) professional considerations in engineering practice. Four degrees of achievement are specified, i.e., unsatisfactory (0), marginal (1), satisfactory (2), and exemplary (3) for which the parenthetical values represent the associated numerical scores.

Courses used for Assessment: ME:4055 (58:055), 'Mechanical Systems Design' (four credit hours) and ME:0099 (58:091), 'ME Professional Seminar' (no credit hours)

ME:4055 (58:055) is a required, four-credit course offered during the senior year. Course topics include design considerations for mechanical engineering systems; strength, deformation, and durability of mechanical elements; safe-life, fail-safe, damage-tolerant design; and standards, product liability, and ethics in design. The course ME:4055 (58:055) requires each student to complete written assignments on Product Liability, Standards, and Engineering Ethics Quiz. These written assignments and final exam questions are used to assess the student's understanding of professional and ethical responsibility.

ME:0099 (58:091) is a required 0-credit course offered during the junior and senior years. This course introduces students to the practical aspects of being a mechanical engineer in the workplace, community, and the world. Professionals from various engineering environments (e.g., industry, consulting, government, education, and graduate study) are invited to discuss the field of mechanical engineering with students. Various topics are discussed depending on the expertise and experience of the speakers, including, but not limited to, the technical aspects of a career in engineering, professional development, professional conduct, ethics, lifelong learning, and global and societal issues related to the engineering profession. Two lectures are provided on ethics. This course was added to the curriculum in the fall of 2013 to assess the performance indicator, *"Ethical considerations in engineering practice."*

Table 4.16. Rubric for Outcome (f)

Performance Indicator	**Degree of Achievement**			
	Unsatisfactory (0)	**Marginal (1)**	**Satisfactory (2)**	**Exemplary (3)**
1. Knowledge of the NSPE code of engineering ethics	Unaware of NSPE code of engineering ethics or other engineering ethics codes formed by professional engineering organizations	Knows that the NSPE code of engineering ethics exists. Knows of many NSPE statements, but does not emphasize that safety is paramount in engineering practice	Knowledgeable about the NSPE code of engineering ethics. Knows that safety is paramount in engineering practice	Very knowledgeable about the NSPE code of ethics. Knows that safety is paramount in engineering practice
2. Ethical considerations in engineering practice	Does not understand the ethical aspects of engineering	Unable to formulate adequate ideas related to ethical practices in engineering	Can formulate adequate ideas related to the ethical practice of engineering	Can formulate excellent ideas in the ethical practice of engineering
3. Professional considerations in engineering practice	Does not understand professional aspects including products' liability	Minimal understanding of professional aspects including products' liability	Understands professional aspects including written communication of products' liability	Complete understanding of professional aspects including written communications of products' liability

<u>Assessment Instruments</u>: Tanle 4.17 describes the assessment instruments pertaining to each performance indicator defined in the rubric of outcome (f).

Table 4.17. Assessment Instruments for Outcome (f)

Performance Indicator	**Assessment Instruments**				
	ME:4055, 'Mechanical Systems Design'				ME:0099, 'ME Professional Seminar'
	Final Exam	Product Liability	Standards	Engineering Ethics Quiz	Ethics Written Assignment
	Problem 1	Written Assignment	Written Assignment		
1. NSPE code of engineering ethics knowledge	X			X	
2. Ethical considerations in engineering practice				X	X
3. Professional considerations in engineering practice		X	X		

(2) <u>Frequency of Assessment</u>

Outcome (f) is assessed once per year (fall semester).

(3) <u>Expected Level of Attainment</u>

The ME Program faculty consider that outcome (f) is attained if the following two dimensions of the performance measure are met for each performance indicator: (1) the average numerical score ≥ 2 and (2) at least 84% of the students have obtained a score ≥ 2. A numerical score equal to two indicates satisfactory performance. The threshold value of 84% is calculated based on the probability, $P[Z \leq 1] = 0.84$, where Z follows the standard normal distribution.

(4) <u>Summary of Evaluation Results and Extent of Outcome Attainment</u>

Table 4.18 presents the assessment results for outcome (f) in terms of both the average scores and percentages of students with scores equal to or greater than 2. The results are broken down for each performance indicator, as described in Table 4.16 and the outcome is assessed for each semester. The numerical results indicate the following:

(i) Both dimensions of the performance measure were met for all three performance indicators in the fall semesters of 2010, 2011, 2012, and 2013. Therefore, outcome (f) was fully achieved.

Continuous improvements and action plans are described in Section 4.B.1.6.

Table 4.18. Assessment Results for Outcome (f)

Semester	Course Number	Performance Indicators: Knowledge of NSPE's code of engineering ethics	Ethical considerations in engineering practice	Professional considerations in engineering practice	Average
(a) Average scores					
Fall 2010	ME:4055	2.5	2.6	2.8	2.6
Fall 2011	ME:4055	2.7	2.5	3.0	2.7
Fall 2012	ME:4055	2.7	2.7	2.4	2.6
Fall 2013	ME:4055:01	2.4	2.78	2.89	2.69
Fall 2013	ME:4055:02	2.8	2.96	2.94	2.9
Fall 2013	ME:0099		2.67		2.67
(b) Percentages of scores exceeding 2					
Fall 2010	ME:4055	79.2	91.7	95.8	95.8
Fall 2011	ME:4055	84.5	84.5	100	96.5
Fall 2012	ME:4055	92.8	94	85.5	95.2
Fall 2013	ME:4055:01	97	96	100	100
Fall 2013	ME:4055:02	100	100	100	100
Fall 2013	ME:0099		89.5		89.5

4.A.7 Outcome (g): an ability to communicate effectively

(1) Assessment Process

Rubric used for Assessment: Table 4.19 presents the rubric used for assessing outcome (g). This rubric is used to assess the ability of a student to communicate effectively orally and in writing. It utilizes four performance indicators that examine students' abilities relative to (1) organization of writing, (2) writing skills, (3) organization of presentations, and (4) presentation skills. Four degrees of achievement are specified, i.e., unsatisfactory (0), marginal (1), satisfactory (2), and exemplary (3) for which the parenthetical values represent the associated numerical scores.

Course used for Assessment: ME:4080 (58:080), 'Experimental Engineering,' (four credit hours); ME:4086 (58:086), 'Mechanical Engineering Design Project,' (three credit hours); ME:4186 (58:186), 'Enhanced Design Experience,' (three credit hours).

ME:4080 (58:080) is a required course offered in the senior year. Students are required to write an individual technical report about designing and conducting experiments and analyzing and interpreting data. This course is has ben found to be well-suited for assessing the ability of students to communicate effectively in writing.

ME:4086 (58:086) is a required capstone design course, and ME:4186 (58:186) is a required design course for the Design EFA, and both courses are offered during the senior year. The goal of these courses is to integrate engineering and science coursework, while concurrently developing written communication, oral communication, and multi-disciplinary teamwork skills. This integration is accomplished by having the students work on a design project that is

technically sound, raises awareness of contemporary issues, and develops appreciation of the economic, global, societal and ethical contexts of engineering work. These courses have been found to be well-suited for assessing the ability of students to communicate effectively in oral presentations.

Table 4.19. Rubric for Outcome (g)

Performance Indicator	Degree of Achievement: Unsatisfactory (0)	Marginal (1)	Satisfactory (2)	Exemplary (3)
1. Organization in writing	No sequence of information. No graphics. Poor discussion and conclusions. Poorly designed contents.	Poor sequence of information. Some graphics but not referenced. Limited discussion and conclusions. Unclear content.	A logical sequence of information is used. Some graphics are used to explain and interpret the text. Proper discussion and conclusions. Clear content.	A logical sequence of information is used. Proper graphics are used to explain and interpret the text. Thoughtful discussion and conclusions. Clear and interesting writing.
2. Writing skills	Numerous grammar and spelling errors. Long and confusing sentences. Poor syntax.	A few grammar and/or spelling errors. Understandable sentences. Fair syntax.	Hardly any grammar and/or spelling errors. Good syntax and sentences.	Error free. Appropriate and concise syntax and sentences.
3. Organization in presentation	No sequence of information. No graphics. Text doesn't match images. Poorly designed layout.	Poor sequence of information. Limited graphics that hardly support the presentation. Insufficient or excessive text for images. Unclear materials and layout.	The student has used a logical sequence of information. Good graphics that support the presentation. Proper text for images. Clear materials and layout.	The student has wisely used sequencing of information. Very good graphics with proper text to support the presentation. Clear and interesting layout.
4. Presentation skills	No eye contact with the audience. Poor body language.	Limited eye contact with the audience. Limited proper body language.	Good eye contact with the audience. Good body language and movement.	Very good eye contact and body language. Talks with clarity. Correct language usage in regard to both the materials and the audience.

Assessment Instruments: Table 4.20 describes the assessment instruments pertaining each performance indicator defined in the rubric of outcome (g).

Table 4.20. Assessment Instruments for Outcome (g)

Performance Indicator	Assessment Instrument	
	Individual technical reports in ME:4080	Final presentations in ME:4086(0186)
1. Organization in writing	The assessment of this performance indicator is based on 1) the use of information in a logical sequence; 2) usage and interpretation of graphics; 3) discussion and conclusions; and 4) clarity of the content.	
2. Writing skills	The assessment of this performance indicator is based on 1) grammar and spelling errors; 2) sentence structure; and 3) syntax.	
3. Organization in presentation		The assessment of this performance indicator is based on 1) the use of information in a logical sequence during presentations; 2) usage and interpretation of graphics; and 3) clarity of layout.
4. Presentation skills		The assessment of this performance indicator is based on 1) eye contact and 2) proper body language.

(2) Frequency of Assessment

Outcome (g) is assessed twice per year (every semester).

(3) Expected Level of Attainment

The ME Program faculty consider that outcome (g) is attained if the following two dimensions of the performance measure are met for each performance indicator: (1) the average numerical score ≥ 2 and (2) at least 84% of the students have obtained a score ≥ 2. A numerical score equal to two indicates satisfactory performance. The threshold value of 84% is calculated based on the probability, $P[Z \le 1] = 0.84$, where Z follows the standard normal distribution.

(4) Summary of Evaluation Results and Extent of Outcome Attainment

Table 4.21 presents the assessment results for outcome (g) in terms of both the average scores and percentages of students with scores equal to or greater than 2. The results are broken down for each performance indicator, as described in Table 4.19, and the outcome is assessed for each semester. The numerical results indicated the following:

(i) The average scores for all four performance indicators, obtained from 2010 to 2014, were greater than 2. The first dimension of the performance measure was met.

(ii) The percentages of students with scores ≥ 2 for all four performance indicators were

mostly greater than the target value of 84% except for the indicator, "*organization in writing,*" in the fall semester of 2010 (73.3%) and the indicator, "*writing skills,*" in the spring semester of 2014 (82.4%). However, there were improvements in the following semesters for the indicator, "*organization in writing*." The slightly lower percentage of 82.4% for the indicator, *writing skills*, in the spring of 2014 that resulted in an average percentage of 79.4% was due, in part, to the use of a new grading scheme that allowed students to estimate their expected grade during the semester. Overall, the second dimension of the performance measure was met and outcome (g) was achieved. The faculty is considering measures to improve the outcomes, e.g., providing comments on preliminary reports.

Continuous improvements and action plans are described in Section 4.B.1.7.

Table 4.21. Assessment Results for Outcome (g)

Semester	Course Number	Performance Indicator				
		Organization in writing	Writing skills	Organization in presentation	Presentation skills	Average
	(a) Average scores					
Fall 2010	ME:4080	2.1	2.2			2.2
	ME:4086			2.5	2.0	2.2
Spring 2011	ME:4080	2.9	2.5			2.7
	ME:4086 (ME:4186)			2.3	2.2	2.2
Fall 2011	ME:4080	2.7	2.9			2.8
	ME:4086			3.0	2.5	2.8
Spring 2012	ME:4080	2.9	2.8			2.8
	ME:4086 (ME:4186)			2.5	2.5	2.5
Fall 2012	ME:4080	2.8	2.8			2.8
	ME:4086			2.5	2.5	2.5
Spring 2013	ME:4080	2.7	2.8			2.7
	ME:4086 (ME:4186)			2.5	2.5	2.5
Fall 2013	ME:4080	3.0	2.7			2.8
	ME:4086			2.5	2.4	2.5
Spring 2014	ME:4080	2.4	2.4			2.4
	ME:4086[(a)]			2.7	2.4	2.6
	ME:4186[(a)]			2.7	2.4	2.6
	(b) Percentages of scores exceeding 2					
Fall 2010	ME:4080	73.3	86.7			73.3
	ME:4086			94.1	91.2	88.2
Spring 2011	ME:4080	100.0	96.7			100.0
	ME:4086 (ME:4186)			96.8	96.8	93.5
Fall 2011	ME:4080	100.0	100.0			100.0
	ME:4086			100.0	100.0	100.0
Spring 2012	ME:4080	95.8	93.8			97.9
	ME:4086 (ME:4186)			100.0	85.2	96.3
Fall 2012	ME:4080	100.0	100.0			100.0

	ME:4086			100.0	90.0	94.0
Spring 2013	ME:4080	89.6	97.0			91.0
	ME:4086 (ME:4186)			100.0	98.2	100.0
Fall 2013	ME:4080	100.0	93.3			100.0
	ME:4086			100.0	87.0	87.0
Spring 2014	ME:4080	86.4	82.4			79.4
	ME:4086[(a)]			100.0	96.9	100.0
	ME:4186[(a)]			100.0	100.0	100.0

(a) The performance indicators, "*Organization in presentation*" and "*Presentation skills,*" were assessed via ME:4086 and ME:4186, respectively. Before the spring semester of 2014, the scores were calculated by combining the scores from the two courses. Beginning with the spring of 2014, the faculty decided to present the data separately for clarity.

4.A.8 Outcome (h): the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

(1) <u>Assessment Process</u>

<u>Rubric used for Assessment</u>: Table 4.22 presents the rubric used for assessing outcome (h). The rubric utilizes three performance indicators, i.e., (1) social concerns; (2) impact of the solution; and (3) impact on the environment and culture. Four degrees of achievement were specified, i.e., unsatisfactory (0), marginal (1), satisfactory (2), and exemplary (3) with the numbers in parentheses representing the numerical scores.

<u>Course used for Assessment</u>: ME:4048 (58:048), 'Engineering Systems Design,' (four credit hours).

ME:4048 (58:048), 'Engineering Systems Design,' is a required design course offered during the senior year. The goal of this course is to integrate engineering and science coursework as it relates to thermo-fluid-related engineering problems, while concurrently developing written communication, oral communication, and multi-disciplinary teamwork skills. This integration is accomplished by having the students work on a design project, which is technically sound, raises awareness of contemporary issues, and develops appreciation of the economic, global, societal and ethical contexts of engineering work.

Table 4.22. Rubric for Outcome (h)

Performance Indicator	Degree of Achievement			
	Unsatisfactory (0)	**Marginal (1)**	**Satisfactory (2)**	**Exemplary (3)**
1. Technical problem and social concerns	Ignorant of link between the technical problem and social issues and trends	Has some knowledge about the link between the technical problem and social issues and trends	Very conversant about the link between the technical problem and social issues and trends.	Very aware of the social issues and trends related to technical problems; knows latest development in the subject area in a larger context.
2. Impact of solution	Could not care less about the impact of technologies on society and its resources.	Is aware of the impact of technologies on society and social issues and trends	Identifies how technologies address impacts on society and social trends.	Insights are offered to address the impact of technical solutions on society and social trends; constraints related to alternate solutions are discussed.
3. Impact on environment and culture	Unaware of how the technology, process, or design will influence environment and culture locally or in a larger context.	Has some knowledge about how technology, processes, and designs will impact the environment and culture.	Very aware of the impact of technology, processes, and designs on the environment and culture.	Is very aware of the impact of technology, processes, and designs on the environment and culture; addresses how to minimize adverse impacts.

<u>Assessment Instruments</u>: Table 4.23 describes the assessment instruments pertaining to each performance indicator defined in the rubric of outcome (h).

Table 4.23. Assessment Instruments for Outcome (h)

Performance Indicator	Assessment Instrument
	ME:4048 Energy Systems Design
1. Technical problem and social concerns	Quiz on the effects and causes of global warming. See sample student Quiz work.
2. Impact of solution	The student will address the feasibility and potential impact of a solar panel system installed in the parking lot of a local mall from several angles that relate to sustainability. See sample student work on homework assignment #1 (Problem 3).
3. Impact on the environment and culture	A PowerPoint presentation on the energy consumption profile of various cities across the globe and their impact on the environment and quality of life indices. See sample student presentations.

(2) <u>Frequency of Assessment</u>

Outcome (h) is assessed once per year (fall semester).

(3) <u>Expected Level of Attainment</u>

The ME Program faculty consider that outcome (h) is attained if the following two dimensions of the performance measure are met for each performance indicator: (1) the average numerical score ≥ 2 and (2) at least 84% of the students have obtained a score ≥ 2. A numerical score equal to two indicates satisfactory performance. The threshold value of 84% is calculated based on the probability, $P[Z \leq 1] = 0.84$, where Z follows the standard normal distribution.

(4) Summary of Evaluation Results and Extent of Outcome Attainment

Table 4.24 presents the assessment results for outcome (h) in terms of both the average scores and percentages of students with scores equal to or greater than 2. The results are broken down for each performance indicator, as described in Table 4.22, and the outcome is assessed for each semester. The numerical results indicate the following:

(i) Both dimensions of the performance measure were met for all three performance indicators. Therefore, outcome (h) was fully achieved.

Continuous improvements and action plans are described in Section 4.B.1.8.

Table 4.24. Assessment Results for Outcome (h)

Semester	Course No.	Performance Indicator			
		Technical problem	Impact of solution	Impact on environment	Average
(a) Average score					
Fall 2010	ME:4048	2.55	2.85	2.86	2.75
Fall 2011	ME:4048	2.69	2.71	2.68	2.69
Fall 2012	ME:4048	2.53	2.78	2.70	2.67
Fall 2013	ME:4048	3.00	2.82	2.67	2.83
(b) Percentages of scores exceeding 2					
Fall 2010	ME:4048	100.0	100.0	100.0	100.0
Fall 2011	ME:4048	100.0	100.0	100.0	100.0
Fall 2012	ME:4048	98.7	100.0	100.0	100.0
Fall 2013	ME:4048	98.8	100.0	100.0	100.0

4.A.9 Outcome (i): a recognition of the need for, and an ability to engage in life-long learning

(1) Assessment Process

Rubric used for Assessment: Table 4.25 presents the rubric used for assessing outcome (i). This rubric was used to assess the ability of students to recognize the need for and engage in life-long learning. The rubric utilizes four performance indicators, i.e., (1) curiosity; (2) responsibility; (3) knowledge translation; and (4) integration. Four degrees of achievement are specified, i.e., unsatisfactory (0), marginal (1), satisfactory (2), and exemplary (3), with the parenthetical values representing the associated numerical scores.

Course used for Assessment: ME:4048 (58:048), 'Energy Systems Design,' (four credit hours) and ME:4055 (58:055), 'Mechanical Systems Design' (four credit hours).

ME:4048 (58:048) is a required design course offered during the senior year. The goal of this course is to integrate engineering and science coursework as it relates to thermal systems and energy-related engineering problems, while concurrently developing written communication,

oral communication, and multi-disciplinary teamwork skills. This integration is accomplished by having the students work on open-ended design problems throughout the course. The students also learn about research issues related to contemporary global issues related to the availability, production, and utilization of energy and sustainable development.

ME:4055 (58:055) is a required design course offered during the senior year. Course topics include design considerations for mechanical engineering systems; strength, deformation, durability of mechanical elements; safe-life, fail-safe, damage-tolerant design; and standards, products' liability, and ethics in design. The course requires each student to complete a technical report on modern wind turbine systems. Various sections of the report are used to assess outcome (i), i.e., recognition of the need for and an ability to engage in life-long learning.

Table 4.25. Rubric for Outcome (i)

Performance Indicator	Degree of Achievement			
	Unsatisfactory (0)	Marginal (1)	Satisfactory (2)	Exemplary (3)
1. Curiosity – seeking out information	Shows little or no interest in outside learning resources.	Requires detailed or step-by-step instructions to complete a task. Assumes that all learning takes place within the confines of the classroom.	Uses a number of sources of information.	Demonstrates ability to learn independently. Demonstrates responsibility for creating learning opportunities.
2. Responsibility – gathering information	Does not use materials outside of those available in the classroom.	Collects adequate information about the problem but not much about related problems.	Collects adequate information about the problem as well as related problems.	Demonstrates capability to think independently. Goes beyond what is required in completing an assignment and brings information from a wide variety of outside sources into assignments.
3. Translation – applying previously learned information	Does not use or recall material learned in earlier coursework.	Recognizes information as having been learned previously, but has difficulty applying it to new situations.	Can recognize and apply previous material to new situations.	Reflects on prior learning to gain new insight. Applies the full range of prior experience to solve novel and multi-faceted problems.
4. Knowledge integration	Restates information. Provides claims or statements without support or evidence.	Has some trouble using materials and concepts that are in a different format from that taught in class.	Careful analysis; good supporting evidence for conclusions.	Is able to understand, interpret, and apply learned materials and concepts in a format different from that taught in class (e.g., different

				nomenclature, understand equations from different textbooks).

Assessment Instruments: Table 4.26 describes the assessment instruments pertaining to each performance indicator defined in the rubric of outcome (i).

Table 4.26. Assessment Instruments for Outcome (i)

Performance Indicator	**Assessment Instrument**	
	ME:4048 Energy Systems Design	ME:4055 Mechanical Systems Design
1. Curiosity – seeking out information	Summarizing TED talks (by Amory Lovins and David MacKay) on solving the world's energy problems.	Introduction section of the report on Modern Wind Turbine Systems. Students are required to describe energy-related challenges faced by modern society; explain how these challenges can impact their work as mechanical engineers; describe technical challenges related to production of wind energy.
2. Responsibility – gathering information	PowerPoint presentation on energy options for various countries in the world. Students are expected to collect data from various sources, appropriately credit sources and collate information to present a coherent case for each country.	Problem Description section of the report on Modern Wind Turbine Systems. Students are required to choose a mechanical component of the wind turbine system (e.g., gears, shaft, rotors, blades, and towers); describe loading conditions and performance requirements related to the chosen component; describe materials and manufacturing processes used to produce the component.
3. Translation – applying previously learned information	Final Project on designing home energy solutions to achieve LEED* certification for a home in various parts of the U.S.	Standards for Design and Operation section of the report. Students are required to describe standards, codes, and safety issues applicable to the chosen mechanical component.
4. Knowledge integration	Final project on designing energy efficient homes for U.S. cities and evaluating their environmental impacts.	New Designs section of the report. Students are expected to describe new designs that could potentially overcome existing technical challenges related to the design of the chosen component or related system.

*LEED: Leadership in Energy and Environmental Design.

(2) Frequency of Assessment

Outcome (i) is assessed once per year (fall semester).

(3) Expected Level of Attainment

The ME Program faculty consider that outcome (i) is attained if the following two dimensions of the performance measure are met for each performance indicator: (1) the average numerical score ≥ 2 and (2) at least 84% of the students have obtained a score ≥ 2. A numerical score equal to two indicates satisfactory performance. The threshold value of 84% is calculated based on the probability, $P[Z \leq 1] = 0.84$, where Z follows the standard normal distribution.

(4) Summary of Evaluation Results and Extent of Outcome Attainment

Table 4.27 presents the assessment results for outcome (i) in terms of both the average scores and percentages of students with scores equal to or greater than 2. The results are broken down for each performance indicator, as described in Table 4.25, and the outcome is assessed for each semester. The numerical results indicate the following:

(i) The average scores for all four performance indicators, obtained from 2010 to 2013, are greater than 2. Thus, the first dimension of the performance measure was met.

(ii) However, the percentage of students with scores ≥ 2 for the performance indicator, "*Responsibility,*" in ME:4055 (58:055) for the fall semester of 2012 was less than the target value of 84%. Thus, corrective actions were taken, and the results of the assessment conducted in the fall semester of 2013 showed that all four performance indicators were fully achieved.

Continuous improvements and action plans are described in Section 4.B.1.9.

Table 4.27. Assessment Results for Outcome (i)

Semester	**Course Number**	**Performance Indicator**				
		Curiosity	**Responsibility**	**Knowledge Translation**	**Knowledge Integration**	**Average**
	(a) Average scores					
Fall 2010	ME:4048	2.94	2.55	2.64	2.65	2.69
Fall 2011	ME:4048	2.48	2.68	2.61	2.71	2.62
Fall 2012	ME:4048	2.86	2.7	2.79	2.79	2.79
Fall 2012	ME:4055	2.4	2.3	2.4	2.4	2.38
Fall 2013	ME:4048	2.82	2.67	2.74	2.46	2.68
Fall 2013	ME:4055	2.95	2.89	2.77	2.84	2.86
	(b) Percentages of scores exceeding 2					
Fall 2010	ME:4048	92.5	100.0	100.0	100.0	98.1
Fall 2011	ME:4048	84.1	100.0	100.0	100.0	96.0
Fall 2012	ME:4048	100.0	100.0	100.0	100.0	100.0
Fall 2012	ME:4055	85.5	79.5	84.3	85.5	85.5
Fall 2013	ME:4048	100.0	100.0	100.0	89	97.5
Fall 2013	ME:4055	98.5	98.5	98.5	98.5	98.5

4.A.10 Outcome (j): a knowledge of contemporary issues

(1) Assessment Process

Rubric used for Assessment: Table 4.28 presents the rubric used for assessing outcome (j). Contemporary issues are defined as topics that challenge modern society and occupy the attention of citizens who are well informed about their nation and the world. Students should be "aware" of the large role that contemporary issues have in the engineering profession. Students should be especially cognizant of the relationships and interactions that occur between technological, social, economic, and political factors that can resolve or exacerbate the problems facing society. Students should also be able to use their knowledge of contemporary issues in solving engineering problems. Thus, the rubric utilizes three performance indicators that examine students' (1) interest and awareness of contemporary topics; (2) knowledge of contemporary topics; and (3) ability to use their knowledge of contemporary issues in solving engineering problems. Four degrees of achievement are specified, i.e., unsatisfactory (0), marginal (1), satisfactory (2), and exemplary (3), with the numbers in parentheses representing the numerical scores.

Course used for Assessment: In the fall semester of 2010 and the spring semester of 2011, this outcome was assessed by ME:0099 (58:091), 'ME Professional Seminar,' (no credit hours). In the spring semester of 2011, the ME faculty suggested that the course used to assess this outcome be changed to ME:4048 (58:048), 'Energy Systems Design,' (four credit hours). Further, in the fall semester of 2012, the ME faculty suggested that ME:4055 (58:055), 'Mechanical Systems Design,' (four credit hours) also be included in the assessment of this outcome. Thus, beginning in the fall of 2012, both courses, totaling eight credit hours, are used together to assess this outcome.

ME:4048 (58:048), 'Energy Systems Design,' is a required design course that is offered during the senior year. The goal of this course is to integrate engineering and science coursework as it relates to thermal systems and energy-related engineering problems, while concurrently developing written communication, oral communication, and multi-disciplinary teamwork skills. This integration is accomplished by having the students work on open-ended design problems throughout the course. The students also learn about and conduct research related to contemporary global issues connected with the production and utilization of energy and sustainable development.

ME:4055 (58:055), 'Mechanical Systems Design,' is a required, four-credit course offered during the senior year. Topics addressed in the course include design considerations for mechanical engineering systems; strength, deformation, durability of mechanical elements; safe-life, fail-safe, damage-tolerant design; and standards, products' liability, and ethics in design.

Table 4.28. Rubric for Outcome (j)

Performance Indicator	Degree of Achievement			
	Unsatisfactory (0)	**Marginal (1)**	**Satisfactory (2)**	**Exemplary (3)**
1. Interest	No awareness of any contemporary issues; shows no interest and never asks questions	Awareness of at least one contemporary issue; shows occasional interest	Awareness of at least two contemporary issues; shows interest most of the time	Awareness of more than two contemporary issues; is enthusiastic about the issues and always asks questions
2. Knowledge	Cannot describe/explain any contemporary issues	Familiarity with (describes/explains) selected contemporary issues, but rarely seeks out new knowledge about the issues	Familiarity with (describes/explains) most contemporary issues; takes active role in increasing knowledge about the issues	Great familiarity with (describes/explains) contemporary issues of all kinds; takes full advantage of available resources to increase knowledge about the issues
3. Use	Cannot demonstrate any connection between contemporary issues and engineering problem solving	Some use of knowledge of contemporary issues in solving engineering problems	Consistent use of knowledge of contemporary issues in solving engineering problems; establishes connection with material learned in other courses	Comprehensive use of knowledge of contemporary issues in solving engineering problems; offers alternative (or opposing) views; can fully relate contemporary issues to material learned in courses

Assessment Instruments: Table 4.29 describes the current assessment instruments pertaining to each performance indicator defined in the rubric of outcome (j). The old assessment instruments were based on an essay on contemporary issues in ME:0099 (58:091), 'ME Professional Seminar.' In particular, the students were asked to answer the following questions in the essay:
(1) Name at least two contemporary issues addressed in a seminar or elsewhere.
(2) Describe these contemporary issues.
(3) Explain how these contemporary issues can impact your work as an engineer.

Table 4.29. Assessment Instruments for Outcome (j)

Performance Indicator	Assessment Instrument	
	ME:4048, 'Energy Systems Design'	ME:4055, 'Mechanical Systems Design'
1. Interest		Introduction section of the report on Modern Wind Turbine Systems. Students are required to describe energy-related challenges that modern society faces; explain how these challenges can impact their work as mechanical engineers; describe technical challenges related to the production of wind energy.
2. Knowledge		Introduction section and Design Challenges section of the report on Modern Wind Turbine Systems. In the Design Section of the report, students are expected to describe existing technical challenges related to the design of the chosen component or related system and how it impacts the performance of the wind turbine systems.
3. Use	Students use their knowledge of energy needs and impacts in evaluating renewable energy options for designing a	Introduction section and New Designs section of the report on Modern Wind Turbine Systems. In the New Designs

	LEED-certified home in various parts of the United States. The report is used as the assessment instrument.	section of the report, students are expected to describe new designs that could potentially overcome existing technical challenges.

(2) Frequency of Assessment

Outcome (j) is assessed once per year.

(3) Expected Level of Attainment

The ME Program faculty consider that outcome (j) is attained if the following two dimensions of the performance measure are met for each performance indicator: (1) the average numerical score ≥ 2 and (2) at least 84% of the students have obtained a score ≥ 2. A numerical score equal to two indicates satisfactory performance. The threshold value of 84% is calculated based on the probability, $P[Z \leq 1] = 0.84$, where Z follows the standard normal distribution.

(4) Summary of Evaluation Results and Extent of Outcome Attainment

Table 4.30 presents the assessment results for outcome (j) in terms of both the average scores and percentages of students with scores equal to or greater than 2. The results are broken down for each performance indicator, as described in Table 4.28, and the outcome is assessed for each semester. The numerical results indicate the following:

(i) In the fall semester of 2010 and the spring semester of 2011, this outcome was assessed by ME:0099 (58:091); the assessment results were improved, resulting in both dimensions of the performance measure being met in the spring semester of 2011.

(ii) In fall semesters of 2011 and 2012, ME:4048 (58:048) was only used to assess the performance indicator "*Use*". Therefore, corrective actions were taken in the fall 2013 semester.

(iii) In the fall semester of 2012, the results from ME:4055 (58:055) showed that both dimensions of the performance measure were essentially met for the three performance indicators. However, the percentage score for the second indicator, "*Knowledge,*" was slightly less than the target value of 84%. Thus, corrective actions were taken in the fall semester of 2013.

(iv) The assessment results in the fall semester of 2013 showed that the three performance indicators were fully achieved.

Continuous improvements and action plans are described in Section 4.B.1.10.

Table 4.30. Assessment Results for Outcome (j)

Semester	Course Number	Performance Indicator			
		Interest	Knowledge	Use	Average
(a) Average scores					
Fall 2010	ME:0099	2.02	2.08	1.87	2.00
Spring 2011	ME:0099	2.10	2.10	2.00	2.10
Fall 2011	ME:4048	NA	NA	2.68	2.68
Fall 2012	ME:4048	NA	NA	2.75	2.75
Fall 2012	ME:4055	2.60	2.30	2.30	2.40
Fall 2013	ME:4048	NA	NA	2.74	2.74
Fall 2013	ME:4055	2.95	2.94	2.87	2.92
(b) Percentages of scores exceeding 2					
Fall 2010	ME:0099	97.7	89.7	79.3	75.9
Spring 2011	ME:0099	100.0	98.0	89.8	89.8
Fall 2011	ME:4048	NA	NA	100.0	100.0
Fall 2012	ME:4048	NA	NA	100.0	100.0
Fall 2012	ME:4055	92.8	81.9	96.4	90.4
Fall 2013	ME:4048	NA	NA	100.0	100.0
Fall 2013	ME:4055	98.5	98.5	98.5	98.5

4.A.11 Outcome (k): an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

(1) Assessment Process

Rubric used for Assessment: Table 4.31 presents the rubric used for assessing outcome (k). This rubric was designed to assess the ability of a student to use modern engineering tools. The rubric utilizes three performance indicators that examine students' abilities to (1) use of CAD software; (2) use engineering packages; and (3) use laboratory equipment. Four degrees of achievement are specified, i.e., unsatisfactory (0), marginal (1), satisfactory (2), and exemplary (3) for which the parenthetical values represent the associated numerical scores.

Course used for Assessment: ME:3052 (58:052), 'Mechanical Systems,' (four credit hours) and ME:4080 (58:080), 'Experimental Engineering,' (three credit hours).

ME:3052 (58:052), 'Mechanical Systems,' is a required course taken by juniors in Mechanical Engineering. The goal of this course is to provide students with the opportunity to develop an understanding of the basic procedures used in the analysis and design of mechanical systems. The course contains laboratory work using advance engineering design and analysis packages.

ME:4080 (58:080), 'Experimental Engineering,' is a required course for seniors in Mechanical Engineering. The course uses modern instrumentation and data acquisition tools along with significant data processing and reporting. These courses are well suited to assess the ability of students to use modern engineering tools.

Table 4.31. Rubric for Outcome (k)

Performance Indicator	Degree of Achievement			
	Unsatisfactory (0)	**Marginal (1)**	**Satisfactory (2)**	**Exemplary (3)**
1. Use of CAD software	Not knowledgeable about CAD software programs; seldom uses them in design.	Knows about CAD software programs; uses them occasionally.	Knowledgeable about CAD software programs; uses them effectively in design.	Very knowledgeable about CAD software programs; uses them very effectively in design; proficient at navigating them to achieve goals.
2. Use of analysis packages	Not knowledgeable about analysis packages; seldom uses them in problem solving and design.	Knows about engineering analysis packages; uses them occasionally.	Knowledgeable about engineering analysis packages; uses them effectively in problem solving and design.	Very knowledgeable about engineering analysis packages; uses them very effectively in problem solving and design; proficient at navigating them to achieve goals.
3. Use of hardware and laboratory equipment	Very limited knowledge about laboratory equipment; no attempts made to learn.	Has general idea of hardware and equipment, but the selection is ineffective; uses them but needs significant assistance.	Knowledgeable about laboratory equipment and hardware; selects appropriate pieces; knows their use for laboratory tests, design, or research.	Same as (2) plus knows hardware limitations and their efficient use; uses them very effectively.

Assessment Instruments: Table 4.32 describes the assessment instruments pertaining to each performance indicator defined in the rubric of outcome (k).

Table 4.32. Assessment Instruments for Outcome (k)

Performance Indicator	Assessment Instrument	
	ME:3052, 'Mechanical Systems'	ME:4080, 'Experimental Engineering'
1. Use of CAD software	Individual laboratory reports: Students are required to generate CAD models using commercial, solid modeling software, and document their procedures.	
2. Use of analysis packages	Individual laboratory reports: Students are required to conduct mechanical analyses using a commercial finite element package. Students must select the appropriate element(s), generate finite element meshes, perform analyses, and demonstrate an ability to evaluate the results.	
3. Use of hardware and laboratory equipment		Log Books in Labs and in Final Project Report. These experimental projects require the students to use instrumentation to complete a fairly complex experiment and to design and conduct an experiment.

(2) Frequency of Assessment

Outcome (k) is assessed once per year based on ME:3052 (58:052) (spring semester) and twice per year based on ME:4080 (58:080) (fall and spring semesters).

(3) Expected Level of Attainment

The ME Program faculty consider that outcome (k) is attained if the following two dimensions of the performance measure are met for each performance indicator: (1) the average numerical score ≥ 2 and (2) at least 84% of the students have obtained a score ≥ 2. A numerical score equal to two indicates satisfactory performance. The threshold value of 84% is calculated based on the probability, $P[Z \leq 1] = 0.84$, where Z follows the standard normal distribution.

(4) Summary of Evaluation Results and Extent of Outcome Attainment

Table 4.33 presents the assessment results for outcome (k) in terms of both the average scores and percentages of students with scores equal to or greater than 2. The results are broken down for each performance indicator, as described in Table 4.31, and for each semester the outcome is assessed. The numerical results indicate the following:

(i) Both dimensions of the performance measure were met for all three performance indicators in then spring and fall semesters of 2011, 2012, and 2013 and in the spring semester of 2014. Therefore, outcome (k) was fully achieved.

Continuous improvements and action plans are described in Section 4.B.1.11.

Table 4.33. Assessment Results for Outcome (k)

Semester	Course Number	Performance Indicator			
		Use of CAD software	**Use of analysis packages**	**Use of hardware and laboratory equipment**	**Average**
(a) Average scores					
Spring 2011	ME:3052	2.0	2.0		2.3
Spring 2011	ME:4080			2.3	
Fall 2011	ME:4080			3	3
Spring 2012	ME:3052	2.5	2.6		2.5
Spring 2012	ME:4080			2.4	
Fall 2012	ME:4080			2.4	2.4
Spring 2013	ME:3052	2.7	2.8		2.7
Spring 2013	ME:4080			2.7	
Fall 2013	ME:4080			2.6	2.6
Spring 2014	ME:3052	2.8	2.9		2.8
Spring 2014	ME:4080			2.9	2.9
(b) Percentages of scores exceeding 2					
Spring 2011	ME:3052	93.8	98.5		92.3
Spring 2011	ME:4080			96.7	96.7
Fall 2011	ME:4080			100.0	100.0
Spring 2012	ME:3052	91.4	92.6		96.9

Spring 2012	ME:4080			89.6	89.6
Fall 2012	ME:4080			100.0	100.0
Spring 2013	ME:3052	100.0	100.0		100.0
Spring 2013	ME:4080			95.5	95.5
Fall 2013	ME:4080			93.3	93.3
Spring 2014	ME:3052	98.5	98.5		98.5
Spring 2014	ME:4080			100.0	100.0

4.A.12 Outcome (l): an ability to work professionally in either thermal or fluid systems engineering, including the design and realization of such systems

(1) Assessment Process

Rubric used for Assessment: Table 4.34 presents the rubric used for assessing outcome (l). This rubric is designed to assess the ability of a student to work professionally in thermal and fluid systems engineering, including the design and realization of such systems. The rubric utilizes three performance indicators that examine students' abilities to (1) identify technical issues involved in designing a thermal and fluid system; (2) identify and account for resource issues and constraints that impact on design; and (3) demonstrate design skills and design innovation, in particular the ability to design large-scale thermal and fluid systems. Four degrees of achievement are specified, i.e., unsatisfactory (0), marginal (1), satisfactory (2), and exemplary (3), with the parenthetical values representing the associated numerical scores.

Course used for Assessment: ME:4048 (58:048), 'Energy Systems Design' (four credit hours).

ME:4048 (58:048) is a required design course offered during the senior year. The goal of this course is to integrate engineering and science coursework as it relates to thermo-fluid-related engineering problems, while concurrently developing written communication, oral communication, and multi-disciplinary teamwork skills. This integration is accomplished by having the students work on open-ended design problems.

Table 4.34. Rubric for Outcome (l)

Performance Indicator	Degree of Achievement			
	Unsatisfactory (0)	Marginal (1)	Satisfactory (2)	Exemplary (3)
1. Identify issues involved in designing a thermal and fluid system	Couldn't identify key design issues; lack of judgment.	Identifies some design issues but has not prioritized them; judgment not adequate.	Has identified most of the design issues and prioritized them; judgment on priorities seems OK.	Has completely identified key design issues and prioritized them; has ranked them based on their importance.
2. Identify and account for resource issues and constraints that impact on design	Unaware of material or design constraints; no resources identified	Has some understanding of constraints and has addressed resources	Well-documented constraints; has addressed resources needed to complete design or system	Has developed alternate plans for resources; has alternate methods of meeting design constraints
3. Demonstrate design skills and design innovation, in particular the ability to design large-scale thermal and fluid systems	Progress is almost non-existent; no skills shown and concept of innovation is non-existent.	Progress is adequate and shows design skills; hardly any design innovation; limited variations.	Good progress with good design skills; limited design innovation; alternatives considered	Progress according to schedule; good design skills; design has many innovations and alternatives.

Assessment Instruments: Table 4.35 describes the assessment instruments pertaining to each performance indicator defined in the rubric of outcome (l).

Table 4.35. Assessment Instruments for Outcome (l)

Performance Indicator	Assessment Instrument
1. Identify issues involved in designing a thermal and fluid system	A homework problem on an energy system choice will be used to assess this indicator. Students will be required to state the technical issues involved in the design and implementation of a specific, practically-relevant system. See sample student work on HW2_Sample1 (Problem 1 on the evaluation of energy-efficient windows).
2. Identify and account for resource issues and constraints that impact on design	Homework to assess the feasibility of an energy-efficient lighting system to replace a conventional system. See sample student work on HW2 (Problem 2 on energy efficient lighting evaluation).
3. Demonstrate design skills and design innovation; in particular, the ability to design large-scale thermal and fluid systems	Take-home, open-ended design problem. The student will demonstrate the ability to set up and solve the relevant equations to design a thermal and fluid system with many interacting components. The case of a waste heat recovery system for a dishwasher was analyzed. See sample student work on HW3 (Problem 2 on heat recovery dishwashing system design).

(2) Frequency of Assessment

Outcome (l) is assessed once per year.

(3) Expected Level of Attainment

The ME Program faculty consider that the outcome (l) is attained if the following two dimensions of the performance measure are met for each performance indicator: (1) the average numerical score ≥ 2 and (2) at least 84% of the students have obtained a score ≥ 2. A numerical score equal to two indicates satisfactory performance. The threshold value of 84% is calculated based on the probability, $P[Z \leq 1] = 0.84$, where Z follows the standard normal distribution.

(4) Summary of Evaluation Results and Extent of Outcome Attainment

Table 4.36 presents the assessment results for outcome (l) in terms of both the average scores and percentages of students with scores equal to or greater than 2. The results are broken down for each performance indicator, as described in Table 4.34, and the outcome is assessed for each semester. The numerical results indicate the following:

(i) Both dimensions of the performance measure were met for all three performance indicators in the fall semesters of 2010, 2011, 2012, and 2013. Therefore, outcome (l) was fully achieved.

Continuous improvements and action plans are described in Section 4.B.1.12.

Table 4.36. Assessment Results for Outcome (l)

Semester	Course Number	Performance Indicator: Identify issues involved in designing a thermal and fluid system	Identify and account for resource issues and constraints that impact on the design	Demonstrate design skills and design innovation; in particular facility to perform design of a large-scale thermal and fluid system	Average
(a) Average scores					
Fall 2010	ME:4048	2.66	2.71	2.78	2.72
Fall 2011	ME:4048	2.19	2.86	2.80	2.61
Fall 2012	ME:4048	2.91	2.80	2.95	2.89
Fall 2013	ME:4048	2.46	2.78	2.55	2.6
(b) Percentages of scores exceeding 2					
Fall 2010	ME:4048	100	95.5	100	98.5
Fall 2011	ME:4048	80.7	100	100	93.6
Fall 2012	ME:4048	100	100	100	100
Fall 2013	ME:4048	89.1	100	93.9	94.3

4.A.13 Outcome (m): an ability to work professionally in mechanical systems engineering, including the design and realization of such systems

(1) Assessment Process

Rubric used for Assessment: Table 4.37 presents the rubric used for assessing outcome (m). The rubric utilizes three performance indicators that examine students' abilities to (1) understand considerations in the design of mechanical systems; (2) apply design criteria for durability; and (3) design or analyze mechanical systems/components. Four degrees of achievement are specified, i.e., unsatisfactory (0), marginal (1), satisfactory (2), and exemplary (3).

Course used for Assessment: ME:4055 (58:055), 'Mechanical Systems Design' (four credit hours).

ME:4055 (58:055) is a required, four-credit course offered during the senior year. Course topics include design considerations for mechanical engineering systems; strength, deformation, durability of mechanical elements; safe-life, fail-safe, damage-tolerant design; standards, products' liability, and ethics in design. The course requires each student to complete written assignments on product liability, standards, and modern wind energy systems. These written

assignments and problems on the final exam are used to assess students' abilities to work professionally in mechanical systems areas, including the design and realization of such designs.

Table 4.37. Rubric for Outcome (m)

Performance Indicator	Degree of Achievement: Unsatisfactory (0)	Marginal (1)	Satisfactory (2)	Exemplary (3)
1. Understanding of considerations in the design of mechanical systems	No understanding of the many considerations in the design of mechanical systems	Has some understanding of the design considerations in mechanical systems	Recognizes and understands the many design considerations in mechanical systems	Very knowledgeable about the design considerations in mechanical systems
2. Ability to apply design criteria for durability	No ability to achieve proper durability	Has some understanding of applying design criteria to achieve proper durability	Recognizes and understands the application of design criteria to achieve proper durability	Very knowledgeable about recognizing and understanding application of design criteria to achieve proper durability
3. Ability to design or analyze mechanical systems and components	Does not understand the design of mechanical systems and components	Has some ability to design mechanical systems and components	Recognizes and understands the design of mechanical systems and components	Complete recognition and understanding of the design of mechanical systems and components

Assessment Instruments: Table 4.38 describes the assessment instruments that pertain to each performance indicator defined in the rubric of outcome (m).

Table 4.38. Assessment Instruments for Outcome (m)

Performance Indicator	Assessment Instruments: Final Exam Problem 5	Product liability written assignment	Standards written assignment	Report on modern wind turbine systems	Final Exam Problem 6
1. Understanding of considerations in the design of mechanical systems		X	X	X	
2. Ability to apply design criteria for durability	X				
3. Ability to design or analyze mechanical systems and components		X	X	X	X

(2) Frequency of Assessment

Outcome (m) is assessed once per year.

(3) Expected Level of Attainment

The ME Program faculty consider that outcome (m) is attained if the following two dimensions of the performance measure are met for each performance indicator: (1) the average numerical score ≥ 2 and (2) at least 84% of the students have obtained a score ≥ 2. A numerical score equal to two indicates satisfactory performance. The threshold value of 84% is calculated based on the probability, $P[Z \leq 1] = 0.84$, where Z follows the standard normal distribution.

(4) Summary of Evaluation Results and Extent of Outcome Attainment

Table 4.39 presents the assessment results for outcome (m) in terms of both the average scores and percentages of students with scores equal to or greater than 2. The results are broken down for each performance indicator, as described in Table 4.37, and the outcome is assessed for each semester. The numerical results indicate the following:

(i) Both dimensions of the performance measure were essentially met for the first two performance indicators, i.e., "*understanding of considerations in the design of mechanical systems*" and "*ability to apply design criteria for durability*," in the fall semesters of 2010, 2011, 2012, and 2013.

(ii) The average scores and percentages of students with scores ≥ 2 for the third performance indicator, "*ability to design or analyze mechanical systems and components*," have been improving over the years. The average scores in the fall semesters of 2011, 2012, and 2013 met the target score, whereas the percentage score for the third indicator in the fall semester of 2012 was still slightly less than the target value of 84. Therefore, corrective actions were taken for the third indicator in the fall semester of 2013. The data collected in the fall semester of 2013 showed great improvement, meeting the target score.

Continuous improvements and action plans are described in Section 4.B.1.13.

Table 4.39. Assessment Results for Outcome (m)

Semester	Course Number	Performance Indicator: Understanding of considerations in the design of mechanical systems	Ability to apply design criteria for durability	Ability to design or analyze mechanical systems and components	Average
(a) Average scores					
Fall 2010	ME:4055	2.9	2.0	1.9	2.3
Fall 2011	ME:4055	2.90	2.47	2.10	2.49
Fall 2012	ME:4055	2.7	2.5	2.3	2.5
Fall 2013	ME:4055:001	2.9	2.3	2.7	2.6
Fall 2013	ME:4055:002	2.97	2.54	2.97	2.82
(b) Percentages of scores exceeding 2					
Fall 2010	ME:4055	100	73.6	68.1	79.2
Fall 2011	ME:4055	100	91.4	76	89.2
Fall 2012	ME:4055	96.4	86.7	81.9	91.6
Fall 2013	ME:4055:001	100	94	99	99
Fall 2013	ME:4055:002	100	100	100	100

4.B Continuous Improvement

4.B.1 Actions Resulting from the Assessment of Student Outcomes

4.B.1.1 Outcome (a): an ability to apply knowledge of mathematics, science, and engineering

Assessment results

Spring 2011: The first performance indicator, "*Application of fundamental principles of science and engineering,*" was slightly below the target threshold of 84%, with 79.4% of students achieving satisfactory or better, and the second performance indicator, "*Use of engineering and mathematical models to solve open-ended problems,*" was met (84%). The third performance indicator, "*Application of advanced mathematical principles to solve problems,*" was 77.8%, slightly below the target threshold of 84%.

Spring 2012: The first two performance indicators demonstrated satisfactory performance. The third performance indicator, "*Application of advanced mathematical principles to solve problems*," was 45.7%, significantly below the target threshold of 84%.

Spring 2013: The first two performance indicators were above the target threshold, and the third performance indicator was 74.1%, slightly below the target threshold of 84%.

Spring 2014: All three performance indicators were above the target threshold. In particular, a significant improvement was observed in the third performance indicator.

Actions taken

Spring 2011, ME3045 (58:045), 'Heat Transfer': James Buchholz
In the evaluation in the spring of 2011, the students' abilities to apply knowledge of mathematics were assessed on a problem in which the students had to manipulate and solve the appropriate form of the heat equation for a given geometry and boundary conditions. The students' performances were marginally satisfactory. In discussions during a ME program meeting, it was decided that this problem was too advanced to be used for assessment in this course.

Spring 2012, ME3045 (58:045), 'Heat Transfer": James Buchholz
Additional time was devoted to the solution of one-dimensional boundary value problems involving the heat equation, i.e., students apply appropriate boundary conditions to fundamental solutions of the heat equation. Informal assessment and feedback were provided through in-class

quizzes.

Spring 2013, ME3045 (58:045), 'Heat Transfer': James Buchholz
Prior to the beginning of the spring semester in 2013, the instructor met with the College of Engineering's Associate Dean of Academic Programs, Keri Hornbuckle, and Professor of Mathematics, Colleen Mitchell. The purpose of the meeting was to discuss differences in terminology and teaching methods used in differential equations and vector calculus courses taught by the Mathematics department. The objective of the discussion was to identify ways to help students make the transition from the study of math to engineering courses in which the math is applied, e.g., in ME:3045 (58:045), 'Heat Transfer,' in particular. During the discussion of the heat equation in ME:3045 (58:045), the instructor engaged students in an open discussion about perceived differences in the courses and weaknesses in their mathematical preparation. These issues were addressed in the lecture. One important issue identified was that most students did not realize that much of the material covered in their differential equations course (methods of solution of differential equations) was not relevant to ME:3045 (58:045), since fundamental solutions to the relevant forms of the heat equation were provided.

Spring 2014, ME3045 (58:045), 'Heat Transfer': James Buchholz
Primary changes were made in this Heat Transfer course, including a) collection and grading of homework assignments from almost every lecture with one problem being selected randomly from each assignment, b) the mid-term exam was scheduled in the evening, allowing 90 minutes rather than the standard 50-minute class period to complete the exam without significantly lengthening the exam, and c) after the exam, the students were given the same exam as a homework assignment, and they were given approximately 36 hours to complete the exam. The results of the original exam were used in the evaluation of the first performance indicator.

4.B.1.2 Outcome (b): an ability to design and conduct experiments, as well as to analyze and interpret data

<u>Assessment results</u>

Spring 2012: The average achievement for the performance indicators, "*Data analysis*" and "*Experiment design*," decreased with respect to previous semesters.

Fall 2012: The third and sixth performance indicators, "*Experimental procedures*" and "*Experiment design*," were below the target threshold of 84%.

Spring 2013: The average scores for all of the six performance indicators were greater than 2, and all of the percentages of students with scores ≥ 2 for the six performance indicators were greater than the target value of 84%.

Fall 2013: All of the average scores for the six performance indicators were greater than 2, and the all of the percentages of students with scores ≥ 2 for the six performance indicators were greater than the target value of 84%.

Spring 2014: Scores were within expected parameters, with a slight decrease in "*Experimental*

Procedures." The target number of 84% of students with satisfactory or higher scores was achieved for all performance indicators, as well as averages above 2.

<u>Actions taken</u>

Fall 2012, ME:4080 (58:080), 'Experimental Engineering': Pablo Carrica
More emphasis was given to the analysis of results and techniques for experiment design. This was enabled by allowing more time to work on reports for the main laboratory assignments.

Spring 2013, ME:4080 (58:080), 'Experimental Engineering': Hongtao Ding
The decrease in performance for the indicators "*Experimental procedures*" and "*Experiment design*" in the fall of 2012 was attributed to the introduction of the more complex data acquisition software, LabView, resulting in more time being spent on teaching LabView and its use for the different laboratories. The two indicators were improved after corrective actions were undertaken in the spring of 2013.

Fall 2013, ME:4080 (58:080), 'Experimental Engineering': Hongtao Ding
The students generally have difficulty in understanding the laboratory manuals for Dynamic System labs, such as lab 2c and lab 2d. Therefore, the lectures were enhanced significantly for dynamic response by showing more computer examples of time and frequency responses.

Spring 2014, ME:4080 (58:080), 'Experimental Engineering': Pablo Carrica
The last experiment before the final project was extended in time to allow for more in-depth analysis of the results and for preparing the written report, which is the main document produced in the course.

4.B.1.3 Outcome (c): an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

<u>Assessment results</u>

Fall 2013: Both dimensions of the performance measure were met for all performance indicators in fall semester of 2010 and in the fall and spring semesters of 2012 and 2013.

Spring 2014: The outcome in the spring semester of 2014 was found to be satisfactory. The scores remained stable and were well above the 84% goal.

<u>Actions taken</u>

Spring 2013, ME:4086 (58:086), 'Mechanical Engineering Design Project' and ME:4186 (58:186), 'Enhanced Design Experience': Andrew Kusiak, Albert Ratner, and Daniel Mineck
The faculty revised the "Capstone Design Individual Experience" form to assess students' abilities on consideration of specific design constraints, such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability constraints. Students in the Mechanical Engineering Design Project (MEDP), the Program of Enhanced Design

Experience (PEDE), and the Virtual International Design Project (VIDP) are required to complete the forms and attach them as appendices to their final design project. The new forms greatly increased the type and depth of information collected, and they have provided a much-improved knowledge base with which to assess the students. Having specific categories in each of the areas enables evaluation of how well all of the students understand each of the constraints as opposed to using a single characterization. While the students have a good general understanding, the instructors intend to delve more closely into the data and to develop additional training and information sessions for the students in areas where particular weaknesses have been identified.

The results obtained from the new form show that the greatest deficits were in political considerations (~12%) and sustainability (~40%). The actions taken to address this include a plan to discuss how political considerations in various countries lead to drastically different products being produced for those specific markets. Then, assessments are made of the effects of these different requirements on the designs the students are working on. For sustainability, the intent is to include material that assesses the sustainability of a product based on how it is manufactured and its projected lifetime. Also, the instructor will work with the instructor of the seminar series to identify a professional engineer who can speak to the students on this topic. A detailed summary of the raw data collected from these forms is posted on the ME Program's Iowa Courses Online (ICON) site.

Spring 2014, ME:4086 (58:086), 'Mechanical Engineering Design Project' (MEDP) and ME:4186 (58:186), 'Enhanced Design Experience,' including (Section 1), 'Program for Enhanced Design Experience' (PEDE), and (Section 2), 'Virtual International Project Teams' (VIPT): Andrew Kusiak, Albert Ratner, and Daniel Mineck: The Department has used a number of approaches to address the shortcomings identified in the spring semester of 2013. Topical speakers from companies, including Ross Wilcox from Rockwell and others from John Deere and Florida Power and Light, have made presentations in the design course on various design challenges and constraints. Departmental seminars, including the Professional Seminar, have increased the number of speakers from industry. The most powerful tool used in increasing student awareness of the broad issues pertinent to design was the portfolio of the projects (particularly in MEDP) offered for selection by the students and the learning experience that takes place in the classroom during the periodic project update meetings. We have witnessed a range of projects that involve the design of product families for overseas markets (e.g., the Commonwealth of Independent States), design of a software platform for collaboration within a multi-national corporation, and design projects making use of big data for corporations with large international presences. In terms of specifics, the MEDP student teams selected 10 industrial projects out of the 22 that were available in the fall semester of 2013 and another eight in the spring semester. PEDE (six projects) and VIPT (one project) broken into several parts with changing teams. It included significant discussions of international issues and the impact of governmental regulations on design decisions. The students showed a good understanding of these issues and the different factors that influence and restrict design choices.

Recommendations: The previous changes appear to have been successful in addressing the previously observed weaknesses. Future improvements will include changes to the wording on the student's self-reporting/survey form to make it clear that the students can cite examples of relevant experience from both their capstone class and from other experiences they have had as

undergraduates.

4.B.1.4 Outcome (d): an ability to function on multidisciplinary teams

Assessment results

Fall 2012: Data were not collected in the spring and fall semesters of 2011, and the outcome was not assessed. Based on the data collected in fall semesters of 2010 and 2012 and the spring semester of 2012, both dimensions of the performance measure were mostly met for all four performance indicators. The only exception was for the third performance indicator, *contribution to teamwork or project*, in the fall semester of 2012, when the score of 80% using ENGR:2760 (57:021) was slightly below the target value of 84%.

Fall 2013: The data collected in the fall of 2013 based on ENGR:2760 (57:021) showed that the third performance indicator, *contribution to teamwork or project*, decreased from the score of 97.9% in the spring semester of 2013 to 82.6% in the fall semester of 2013. This was explained by the very low enrollment of ME students in the fall of 2013.

Spring 2014: The data collected in the spring of 2014 based on ENGR:2760 (57:021) when 96 ME students were enrolled showed that the third performance indicator, *contribution to teamwork or project*, increased back to 96.9%. Furthermore, all the data collected in ME:4086 (58:086), 'Mechanical Engineering Design Project,' ME:4186 (58:186), 'Enhanced Design Experience,' and ENGR:2760 (57:021), 'Design for Manufacturing' showed that both dimensions of the performance measure were met for all performance indicators.

Actions taken

Fall 2012/Spring 2013, ENGR:2760 (57:021), 'Design for Manufacturing': Ibrahim Ozbolat
Although the project was posted very early, the tendency of the groups was to finalize the implementation of the project during the submission week, and some students had conflicts with their individual assignments in other courses. Thus, we introduced sub-deadlines for the project to distribute the overall load uniformly over the semester, leaving less work for students to do during the submission week. We expect that students will participate in group meetings regularly due to multiple sub-deadlines, particularly during the second half of the semester. The third performance indicator was monitored in the spring of 2013 offering of ENGR:2760 (57:021) to determine the effect of the changes that were implemented. An improvement in the third performance indicator for ENGR:2760 (57:021) was observed when the sub-deadlines were introduced and more time was allocated for the project near the end of the semester. The other indicators showed satisfactory results as usual.

Spring 2013, ME:4086 (58:086), 'Mechanical Engineering Design Project,' and ME:4186 (58:186), 'Enhanced Design Experience': Andrew Kusiak, Albert Ratner, and Daniel Mineck
The faculty revised the student peer evaluations from an assessment instrument for outcome (d) to assess "*Intra-team communication skills*" as suggested by the survey recommendation about enhancing communication in a team (Section 2.E.2). The results of the assessment showed that the students are very good at intra-team communication, with an average score of 2.8/3.0 across

all Capstone Design projects. An interesting effect was apparent between the one-semester projects and the two-semester projects in that the standard deviation decreased from 0.4 for the one-semester projects to 0.2 for the two-semester projects. This implies that the extra time in the projects had the greatest impact on the poorest performers, and, in fact, none of the students scored below 2.5.

The faculty revised the Capstone Design Individual Experience form to include questions that allowed students to document their efforts of identifying, initiating contact, and working with other professionals, leading to better understanding of the benefits of learning and functioning in a multi-disciplinary team setting. Beginning with the spring semester of 2013, students in ME:4086 (58:086) and ME:4186 (58:186) have been required to fill out the assessment form. The results show that the students interacted with a range of professions, including people in sales and marketing at both potential and current suppliers and the sponsor's sales/dealership personnel. They also interacted with various engineering personnel, including computer science professionals, who assisted them in virtual reality and related modeling and simulation; electrical and civil engineers (depending on the project); and mechanical engineers with expertise in various specialties.

The focus of continuous improvement for AY 2013/14 was to enhance students' understanding of sustainability and governmental/political effects. These will serve as the drivers to introduce the students to professionals who work in these areas so as to assist the students in developing a better appreciation of these issues and their impact on engineering. This will be done through both direct meetings and classroom-based, case-study discussions.

Fall 2013/Spring 2014, ENGR:2760 (57:021), 'Design for Manufacturing': Ibrahim Ozbolat
The indicators were all satisfactory, so no specific action was proposed. The instructor will continue to work on enhancing the delivery of the course and trying to identify new areas for enhancement.

Spring 2014, ME:4086 (58:086), 'Mechanical Engineering Design Project,' and ME:4186 (58:186), 'Enhanced Design Experience': Andrew Kusiak, Albert Ratner, and Daniel Mineck: An additional project status update meeting was introduced in ME:4086 (58:086) because it appeared that the primary issues were that the students were not aware of the different skills they were demonstrating and that it took detailed questioning to extract the information from them. Also, there were some editorial changes made to the existing forms to help identify the information of interest.

Recommendations: For ME:4186 (58:186), the project experience form should be revised to make it clear to the students that they should include experiences from their entire time as undergraduate students and not just things from their capstone design experience. The project experience form also was used for outcome (c), and a similar recommendation was made there.

4.B.1.5 Outcome (e): an ability to identify, formulate, and solve engineering problems

Assessment results

Spring 2012: The average scores for all performance indicators satisfied the target threshold of

≥ 2. However, the percentage of students with scores ≥ 2 for the performance indicator, "*Analysis and interpretation of problem solutions,*" was less than the target value of 84%.

Spring 2013: Both the average and percentage scores for all performance indicators met the target thresholds.

Spring 2014: Both the average and percentage scores for all performance indicators met the target thresholds.

Actions taken

Spring 2013, ME:3052 (58:052), 'Mechanical Systems': Hiroyuki Sugiyama
Professor Sugiyama joined the Department in the spring semester of 2013. In the ME:3052 (58:052), Mechanical Systems' course, Professor Sugiyama emphasized "modeling and numerical errors" in the finite element (FE) section of the course so that students could achieve a better understanding of model verification and validation. The component of "modeling and numerical errors" was missing in the previous years, and it could have been one of the reasons students did not do well in the discussion and evaluation sections in the computer project that was used to evaluate the performance indicator "Analysis and interpretation of problem solutions." This performance indicator requires students to compare finite element solutions with those calculated by hand. With this content, students gained a more specific awareness of the modeling and numerical errors in FE solutions. Furthermore, Professor Sugiyama and the TAs explained how the students could develop a reduced model (as required in the project report) that could be solved by hand. This was done on an individual basis during the computer laboratory session. The students signed up for computer laboratory to work on the project individually, and, at that time, explanations were provided regarding model reduction for the purpose of comparative analysis. In summary, in previous years, students had difficulty in developing an appropriate model that was solvable by hand for the purpose of comparison. In 2013, more emphasis was placed on the modeling aspects in the course, and detailed instructions for developing an appropriate reduced model in the project were provided to students in the computer laboratory sessions.

Spring 2014, ME:3052 (58:052), 'Mechanical Systems': Hiroyuki Sugiyama
No action was taken.

4.B.1.6 Outcome (f): an understanding of professional and ethical responsibility

Assessment results

Both dimensions of the performance measure were met for all performance indicators in all semesters. Therefore, outcome (f) was fully achieved based on the current rubric.

Actions taken

Spring 2013, 'Professional Seminar': Sharif Rahman and Pavlo Krokhmal
Based on the discussion in the MIE meeting on February 12, 2013, and the Mechanical Systems faculty meeting on February 13, 2013, a consensus was reached that ME Professional Seminars provide an appropriate basis for performing additional assessment of outcome (f).

Beginning in the fall of 2013, ME undergraduates have been exposed to a new professional seminar series. A seminar series in a given year will target one of two sets of professional skills, i.e., (1) ethics and business practices or (2) leadership. In the new format, the focus of the seminar series will alternate between the two sets of professional skills.

Fall 2013, ME:4055 (58:055), 'Mechanical Systems Design' (MSD): Olesya Zhupanska
In 2013, the assessment instruments were completely redesigned. The outcome was assessed using written assignments on product liability, standards, and engineering ethics. The final exam also included questions to assess the students' knowledge of NSPE's Code of Ethics. Topics in the course related to product liability, standards, and engineering ethics were revised. Several guest speakers (from industry, Law School, and the UI ADA compliance office) were invited to give lectures.

Fall 2013, ME:0099 (58:091), 'Professional Seminar': Kyung K. Choi
In 2013, the outcome was assessed using written assignments on engineering ethics. A guest speaker was invited to give two lectures.

4.B.1.7 Outcome (g): an ability to communicate effectively

__Assessment results__

Fall 2013, ME:4086 (58:086), 'Mechanical Engineering Design Project,' and ME:4186 (58:186), 'Enhanced Design Experience': Hongtao Ding, Andrew Kusiak, Albert Ratner, and Daniel Mineck: Both the average and percentage scores for all performance indicators obtained from 2010 to 2013 met the target thresholds. Therefore, outcome (g) was fully achieved.

Spring 2014, ME:4080 (58:080), 'Experimental Engineering,' ME:4086 (58:086), 'Mechanical Engineering Design Project,' and ME:4186 (58:186), 'Enhanced Design Experience': Pablo Carrica, Andrew Kusiak, Albert Ratner, and Daniel Mineck: The outcome was assessed using ME:4080 (58:080), 'Experimental Engineering,' ME:4086 (58:086), 'Mechanical Engineering Design Project,' and ME:4186 (58:186), 'PEDE and VIPT.' The assessment results indicated that the students' writing and presentation skills were satisfactory, although the percentage score for the indicator, *writing skills,* in the spring of 2014 was 82.4%, which was slightly less than the target threshold of 84%. Overall, the scores over multiple semesters remained stable, with at least 80% of the students meeting the expected performance level.

__Actions taken__

Spring 2013, ME:4086 (58:086), 'Mechanical Engineering Design Project, and ME:4186 (58:186), 'Enhanced Design Experience': Andrew Kusiak, Albert Ratner, and Daniel Mineck: No action was taken.

Fall 2013, ME:4086 (58:086), 'Mechanical Engineering Design Project,' and ME:4186 (58:186), 'Enhanced Design Experience': Hongtao Ding, Andrew Kusiak, Albert Ratner, and Daniel Mineck:
No action was taken.

Spring 2014, ME:4080 (58:080), 'Experimental Engineering,' ME:4086 (58:086), 'Mechanical Engineering Design Project,' and ME:4186 (58:186), 'Enhanced Design Experience': Pablo Carrica, Andrew Kusiak, Albert Ratner, and Daniel Mineck:
The faculty is considering implementing measures to improve the students' performance, including paying more attention to written reports early in the curriculum and providing comments on draft reports. Grading standards and expectations also will be analyzed.

4.B.1.8 Outcome (h): the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

__Assessment results__

Both dimensions of the performance measure were met for all performance indicators. Therefore, outcome (h) was fully achieved.

__Actions taken:__

Fall 2011, ME:4048 (58:048), 'Engineering Systems Design': H. S. Udaykumar
This assessment was based on a new approach to teaching the course, i.e., using the TILE (Spaces to Transform, Interact, Learn, Engage) classrooms that facilitate group activity, peer-assisted learning, and multimedia sources of information. Students were asked to create a blog on which they would record the the information they acquired based on reading assigned and self-collected material pertaining to the issue of energy and its sustainable production and use.

Fall 2012, ME:4048 (58:048), 'Engineering Systems Design': H. S. Udaykumar
After some reflection and consultations with the TAs from past semesters, it was decided that the blog was difficult to grade because information was organized differently by each group, and the content was not well managed. Therefore, the student blog was replaced by a PowerPoint presentation that the students designed and developed over a period of about a month by performing in-depth analyses of the energy profiles of a country/city chosen from across the spectrum of high energy-consuming entities to low energy-consuming entities. The students looked at the efficiencies of the various entities in terms of energy use, and they correlated the energy profiles they obtained with quality-of-life indicators.

Fall 2013, ME:4048 (58:048), 'Engineering Systems Design': H. S. Udaykumar
Lectures in this semester were podcast and placed on ICON so that students could view them at any time. This is in line with the flipping of the classroom pedagogy adopted in this semester.

4.B.1.9 Outcome (i): a recognition of the need for, and an ability to engage in life-long learning

__Assessment results__

Fall 2012: The percentage of students with scores $\geq$ 2 for the performance indicator, "*Responsibility*," in ME:4055 (58:055) was less than the target value of 84%.

Fall 2013: Both dimensions of the performance measure were met for all performance indicators. Thus, outcome (i) was fully achieved.

Actions taken

Spring/Fall 2013, ME:4055 (58:055), 'Mechanical Systems Design': Hongtao Ding and Olesya Zhupanska
A 20-minute introduction to the design of modern wind turbines will be added to help the students with their technical reports on wind turbine systems.

Fall 2013, ME:4055 (58:055), 'Mechanical Systems Design': Hongtao Ding and Olesya Zhupanska
The issue concerning the low percentage of students who met the "*responsibility*" indicator at the desired level in the fall of 2012 was resolved as demonstrated by the improved score. No further actions were taken.

4.B.1.10 Outcome (j): a knowledge of contemporary issues

Assessment results

Fall 2012: In the fall semesters of 2011 and 2012, the collection of data from ME:4048 (58:048) did not cover all three performance indicators individually, as indicated below. In the fall semester of 2012, the results from ME:4055 (58:055) showed that both dimensions of the performance measure were essentially met for the three performance indicators. However, the percentage for the second indicator "*knowledge*" was slightly less than the target value of 84%.

Fall 2013: The assessment results showed that outcome (j) was satisfactorily demonstrated by the students. Therefore, outcome (j) was fully achieved.

Actions taken

Spring 2013, ME:4048 (58:048), 'Energy Systems Design': H. S. Udaykumar
The assessment of outcomes for the fall of 2011 was transitioned from ME:0099 (58:091) to ME:4048 (58:048), 'Energy Systems Design.' In the fall of 2011, the assessment was performed using a large-scale project, but it was difficult to effectively separate the performance indicators of the outcomes in the grading process. The assessment of the outcome was based on a rather large effort on the part of the students, i.e., a semester-end project on LEED certification with many conjoined and interwoven parts. The outcome had just been transitioned to ME:4048 (58:048), 'Energy Systems Design' from other courses, and it was not clear to the instructor how to map the large problem to the individual outcomes. Even though the numerical value in the assessment document for the assessed outcome is listed under the performance indicator, "*Use*," in reality, the problem tested the students on "*Interest,*" "*Knowledge,*" and "*Use.*" It was difficult to separate it into the individual components of "*Interest,*" "*Knowledge,*" and "*Use.*" After some reflection and discussion in the ME Program meetings, it was felt that an additional course would be useful to help assess this outcome. It was decided that ME:4055 (58:055), 'Mechanical Systems Design,' would be a good venue to parse the different individual indicators since has been used since the fall of 2012 to obtain data on the individual components of outcome

(j).

Fall 2013, ME:4048 (58:048), 'Energy Systems Design' (ESD), and ME:4055 (58:055), 'Mechanical Systems Design' (MSD): U. S. Udaykumar and Olesya Zhupanska
No further actions were taken.

4.B.1.11 Outcome (k): an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Assessment results

Both dimensions of the performance measure were met for all performance indicators in all semesters from 2011 to 2014. Therefore, outcome (k) was fully achieved.

Actions taken

Spring 2013, ME:4080 (58:080), 'Experimental Engineering': Hongtao Ding
LabView software was used for data acquisition and signal processing instead of the older DASYLab software. Teaching LabView starts in 'Engineering Instrumentation,' and it continues in 'Experimental Engineering.' Data acquisition occurs in almost all experiments in both 'Engineering Instrumentation' and 'Experimental Engineering.'

Spring 2013: Mechanical Systems Faculty
Two new mechanical systems faculty, Professors Hongtao Ding and Hiroyuki Sugiyama, joined the Department in the fall of 2012 and the spring of 2013, respectively. Thus, the Mechanical Systems faculty has been revamping ME:3052 (58:052), 'Mechanical Systems' and ME:4055 (58:055), 'Mechanical Systems Design' (Section 4.B.3). Implementation of the revised sequence began in the spring semester of 2014. There is a plan to expand 'Finite Element' from eight hours to ten hours. The laboratory section will be increased accordingly, from four hours to six hours. More emphasis will be placed on laboratory assignments that involve the joint use of CAD software and the Finite Element program.

Currently, our students learn Pro/E in ENGR:2760 (57:021), 'Design for Manufacturing.' They use Pro/E in ME:3052 (58:052), 'Mechanical Systems.' Students who take ME:4115 (58:115), Finite Element I, and ME:4110 (58:110), 'Computer Aided Engineering,' will have opportunities to use Pro/E again. ANSYS is introduced in ME:3052 (58:052), 'Mechanical Systems,' and it is used extensively in ME:4115. ABAQUS is used in ME:4110.

4.B.1.12 Outcome (l): an ability to work professionally in either thermal or fluid systems engineering, including the design and realization of such systems

Assessment results

Both dimensions of the performance measure were met for all performance indicators in the fall semesters of 2010, 2011, 2012, and 2013. Therefore, outcome (l) was fully achieved.

Actions taken

Fall 2012, 2013: No action was taken.

4.B.1.13 Outcome (m): an ability to work professionally in mechanical systems engineering, including the design and realization of such systems

Assessment results

Fall 2012: Both dimensions of the performance measure were essentially met for the first two performance indicators, i.e., "*understanding of considerations in the design of mechanical systems*" and "*ability to apply design criteria for durability.*" The average scores and percentages of students with scores ≥ 2 for the third performance indicator, "*ability to design or analyze mechanical systems and components,*" have been improving over the last few years. Even so, the percentage score for the fall semester of 2012 was slightly less than the target value of 84%. Therefore, corrective actions are required for the third indicator.

Fall 2013: The outcome was assessed using the ME:4055 (58:055), 'Mechanical Systems Design' (MSD) course. The new assessment instruments were used, and the students' performances were found to be satisfactory.

Actions taken

Spring/Fall 2013, ME:4055 (58:055), 'Mechanical Systems Design': Hongtao Ding and Olesya Zhupanska
The students had some difficulty in applying different failure theories for fastener design. This will be improved by giving more examples on failure prevention in fastener design or by redesigning the assessment instruments. The 'Mechanical Systems' faculty met and discussed revamping several related courses. Thus, in the fall of 2013, the assessment instruments were completely redesigned. The outcome was assessed using written assignments on product liability, standards, and modern wind energy systems. The final exam also included questions that were designed to assess the students' ability to apply design criteria for durability. Course topics related to product liability and standards were revised. Several guest speakers (from industry, Law School, and the UI ADA Compliance Office) were invited to offer lectures.

4.B.2 Actions Resulting from Surveys and Interviews

4.B.2.1 Survey results and actions

The following surveys were used to obtain feedback concerning student outcomes.

1. Survey of exiting undergraduate seniors (twice a year)
2. Survey of the design project mentor and/or sponsor (twice a year)
3. Survey of design project judges (twice a year)

The numerical scores were as follows: 1 (strongly agree), 2 (moderately agree), 3 (slightly agree), 4 (slightly disagree), 5 (moderately disagree) and 6 (strongly disagree). The survey results are summarized in Table 4.40 and Table 4.41.

Actions taken

For most outcomes, the survey results fall in the categories between 'strongly agree' and 'moderately agree' with the exceptions of outcomes (g), *an ability to communicate effectively* and (i), *a recognition of the need for, and an ability to engage in, life-long learning*. The low scores for outcome (i) from the design project mentor/sponsor survey and the design judge surveys were due to their not having an adequate basis to make a judgment. For outcome (g), there was a discrepancy between the senior exit survey and the design project mentor/sponsor and judge surveys. Based on the written comments, it was determined that the low scores were due to one outlier group, unreadable charts, and/or small fonts.

Regarding outcome (m) and elective courses for solid modeling, in the spring semester of 2013, the Design EFA coordinators, Professors Kyung K. Choi and Sharif Rahman, investigated this suggestion. They examined the syllabi and course materials for the following courses that emphasize the use of Pro/E or other solid modeling software packages, i.e., BME:2710 (051:063), 'Engineering Drawing, Design, and Solid Modeling,' and CEE:2240 (053:040), 'Introduction to Computer Aided Design-3D Design'. They recommended that these courses not to be listed in the Design EFA's General Electives. However, these courses could be taken by students if they select a tailored EFA. Also, please refer to 0 concerning the revamping of the 'Mechanical Systems' courses and for a discussion of Pro/E and FEM software.

The survey results also indicated that the curriculum should be enhanced in the areas of software skills, communication in a team, and leadership (Section 2.E.2), and the resulting actions are:

1. Software skill:
Actions:
Please refer to the actions described in Section 4.B.1.11.

2. Communication in a team:
Action:
In the spring of 2013, a new performance indicator "intra-team communication skills" was added to assess outcome (d), *an ability to function on multi-disciplinary teams*.

3. Leadership:
Action:

The faculty discussed including topics on leadership along with professional and ethical responsibility in the professional seminars (Section 4.B.1.6). These topics have received increased coverage in the College-wide seminars and Departmental professional seminars.

4. Hands-on experience:

Action:

The faculty discussed the suggestion concerning the need for more hands-on experience. In fact, our students gain significant hands-on experience in ENGR:2760 (57:021), 'Design for Manufacturing.' This course requires student teams to design and manufacture a 1/18 scale electric car, which must be driven by an electric motor that is powered by a standard battery. Groups are free to use any appropriate traditional manufacturing techniques, such as milling, turning, drilling, sawing, welding, bending, and grinding to manufacture the chassis, wheels, and shafts designed using CAD software; however, the chassis must be partially or fully manufactured by a computer numerically controlled (CNC) milling process using a standard plastic workpiece. Considerable effort are placed on the design process and its constraints, the depth and completeness of understanding of the design problem, the quality of the engineering drawings, construction techniques, the creativity of the solution, the ability of the team to work together, and the implementation of the design. A competition is held before the week of the final exam. Groups should complete a 7-ft race in the shortest time, where time will be used as the performance metric. Thus, the faculty concluded that our students have gained sufficient hands-on experience during the design processes in ENGR:2760 (57:021).

Table 4.40. Summary of Mean Scores of the Surveys

Survey	Student outcomes, Fall 2012												
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)
Senior exit int.	1.61	1.79	1.72	1.26	1.63	1.38	1.45	1.56	1.34	1.91	1.72	2.10	1.94
Project mentors	1.36	2.18	2.09	1.33	1.55	2.09	2.18	2.18	2.29	1.56	1.64	2.43	1.33
Project judges	2.11	1.44	1.56	1.33	1.44	1.71	2.78	1.63	3.80	1.50	1.22	1.63	1.56

Survey	Student outcomes, Spring 2013												
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)
Senior exit int.	1.73	1.80	1.60	1.33	1.33	1.40	1.27	1.47	1.40	1.73	1.40	1.73	1.80
Project mentors	2.14	1.57	2.57	1.33	2.57	2.43	1.86	2.71	2.60	2.57	1.57	3.00	2.43
Project judges	2.00	2.20	1.60	2.60	2.00	1.40	1.75	1.60	4.00	2.00	2.60	2.00	1.50

Survey	Student outcomes, Fall 2013												
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)
Senior exit int.	1.25	1.50	1.75	1.13	1.38	1.25	1.25	2.00	1.13	1.25	1.50	1.75	1.38
Project mentors	1.67	2.00	2.00	1.67	2.00	1.67	2.67	2.67	2.00	1.67	2.00	1.50	2.50
Project judges	2.43	1.57	1.29	1.14	1.67	2.14	1.71	1.86	2.60	1.83	1.57	2.40	1.43

Survey	Student outcomes, Spring 2014												
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)
Senior exit int.	1.40	1.53	2.07	1.40	1.43	1.47	1.60	1.67	1.33	2.13	1.93	2.27	1.80
Project mentors	1.89	3.00	2.25	2.00	1.89	3.33	2.22	2.13	2.25	3.43	2.00	3.75	2.33
Project judges	2.57	1.57	2.00	2.50	2.43	2.50	1.57	1.83	2.00	2.00	1.43	1.71	1.57

Table 4.41. Summary of Written Comments of the Surveys

Survey	Written comments, Fall 2012
Senior exit interview	(l) I would rather work with fluids or dynamics over thermal. (m) Elective course should be available for both Pro/E and Solidworks.
Project mentors	(h) I have not had a chance to observe it. (i) I have not had a chance to observe this. (l) Was not part of any project.
Project judges	(g) Wide range of communication abilities demonstrated. Specific issues for many were unreadable charts (mostly due to small font) and lots of um's and ah's; One group lagged dramatically. (i) Not sure if I had any basis upon which to make a judgment on this; needs to be demonstrated.

Survey	Written comments, Spring 2013
Senior exit interview	(General comment) • I believe there are too many solution manuals out there, and students are just memorizing the information instead of learning it. • The best experience is undergraduate research. • Offer different design courses: AutoCAD, Revit, Solidworks, etc. • The math department does not convey to us why we are learning the material. • I think it would be good to promote more undergraduate research.
Project mentors	(a) I only met with the students twice, but they seemed capable. (c, e) Unfortunately, we were unable to attend the final presentation, and have not seen the final project results. (f) I have no evidence or experience on which to base such a judgment. (h, i, j, l, m) I have insufficient information on which to base an answer to this question.

Project judges	(i) Difficult to determine with such little time; no information to base an opinion on this. (k) I didn't see many cases of projects that effectively applied these analysis tools or fundamental "back of the envelope" assessments. (General comment) I did not see the students having a clear idea of how to use what I would hope they learned in their other classes. There was minimal analysis and many of the projects seemed to be more marketing in nature than engineering, so part of the problem was that they did not have a need to do much analysis.

Survey	**Written comments, Fall 2013**
Senior exit interviews	(General comment) Have professors more focused on teaching than their personal research goals.
Project mentors	(General comment) We had a great group of students who were able to solve the problem at hand to a standard of a Deere engineer. The students were well versed in engineering theory. However, the majority of a Mechanical Engineer's job is to provide schedule and budget impacts while solving the problem as quickly and efficiently as possible. I feel the students would benefit from more application of the theory in conjunction with the economic impacts that their design decisions have on the schedule and budgets in both the short term and long term. Also, engineers are not allowed to just sit in cubicles anymore, they need to have a strong foundation in communication across disciplines and cultures.
Project judges	(f) Did not recall specific instances of this - so will respond accordingly. (i) Difficult to tell. (General comment) So my additional areas for specific feedback separate from specific questions. One area that I am particularly biased towards is economic feasibility of solutions. In having made the same transition (undergraduate / graduate degree -> industry) this is a critical component of the majority of the students' future success. The projects students are working are good cross section of engineering issues faced in industry. The hands-on project activities will enhance their knowledge and skills required in coming years.

Survey	**Written comments, Spring 2014**
Senior exit interviews	(General comment) • Add more classes that are solely based on learning certain programs such as proE, Ansys, abaqus, etc. • I think there needs to be more emphasis on preparing students for the industry. My senior design project has shown me that I have not learned enough skills, beyond theory, to design and create a product. • Students need more training in Creo or similar programs. • Somehow, earlier on, it would definitely be beneficial to provide a student with better context as to how the skills they are currently learning are going to transfer. E.g. A student in Statics might be given a problem that shows how important Statics is in Mechanical Systems. The one downside of the curriculum(and I see this as a built-in problem) is that the students have to learn everything separately without the chance to put it all to gather in the big picture classes such as Mechanical Systems Design and Energy Systems Design. • The lab equipment and lab procedures for experimental engineering need to be updated. Their procedures are out of date and a lot of the equipment is shotty.
Project mentors	(b) This project didn't require experiments (l) The project did not require such detail. (f, j) I assume so. (f) Some students come to the work place in hoodie sweatshirts and without knowledge of the company. (General comment) Overall - job well done. However, student participation tapering off towards the end of semester. Need to address this. It's a well-run program. The student interviews uncovered just one area that I felt offered an opportunity for improvement, which was understanding contemporary issues. Thanks!!
Project judges	(a) In general, there was a lack of adequate quantitative analysis. (d) Very difficult to judge this one from a 20 minute presentation. (e) Strong on defining but weak on solving. (f) Difficult to determine. (General comment) I encountered very few students whom I thought were really enthusiastic about engineering. The seemed to all want to get into management as quickly as possible. I think more emphasis on fundamentals and basic engineering approaches would allow them to get a better vision of the overall system and have more appreciation for the role of engineering and innovation. The students that I talked to seemed to almost exclusively on business aspects, which while important are not the end-all. Disappointed at how several projects stopped at CAD; I expected at least minimal mockups.

4.B.2.2 Senior interview results

In the spring of 2013, the end of the semester Senior Project Presentation night was scheduled on May 9, and the Industrial Advisory Board meeting was scheduled on May 10. The ME and IE ABET committees decided to arrange one-on-one interviews for all of our senior students by either board members or project judges from various companies. Since then, the interviews have been conducted twice, i.e., in the springs of 2013 and 2014. The interviews allowed assessment and evaluation of the achievement of some student outcomes from the industrial perspective. The committees chose two outcomes for assessment. They are outcome (i), *a recognition of the need for, and an ability to engage in, life-long learning* and outcome (j), *a knowledge of contemporary* *issues*. The board members and judges indicated that the interviews were helpful for them to know better about the ABET process and the needs of the program. The board members and project judges scored the achievement of these outcomes based on their respective rubrics in Table 4.25 and Table 4.28. A summary of the interviews is shown in Table 4.42. Overall, the two dimensions of the performance measure were met for both outcomes.

Table 4.42. Summary of Senior Interviews Conducted by Advisory Board Members and Judges

Semester	Outcome (i) Performance Indicators				
	Curiosity	**Responsibility**	**Knowledge Translation**	**Knowledge Integration**	**Average**
	(a) Average scores				
Spring 2013	2.5	2.5	2.5	2.5	2.5
Spring 2014	2.4	2.4	2.4	2.5	2.4
	(b) Percentages of scores exceeding 2				
Spring 2013	94.2	94.2	100.0	98.0	98.0
Spring 2014	100.0	98.4	100.0	98.4	98.4

Semester	Outcome (j) Performance Indicators			
	Interest	**Knowledge**	**Use**	**Average**
	(a) Average scores			
Spring 2013	2.2	2.1	2.0	2.1
Spring 2014	2.3	2.5	2.5	2.4
	(b) Percentages of scores exceeding 2			
Spring 2013	93.9	87.8	85.1	85.7
Spring 2014	92.1	96.8	98.4	90.5

4.B.3 Other Actions

The actions described in this section resulted primarily from discussions at ME program faculty meetings. These actions were organized by courses.

ME:3351 (58:051): 'Engineering Instrumentation'

ME:3351 (58:051), 'Engineering Instrumentation,' was first offered in the fall of 2011. This course, which replaced the four s.h. 57:018, 'Principles of Electronic Instrumentation,' taught by the Department of Electrical and Computer Engineering, was reviewed during 2010-2011. In the review, it was found that, from a Mechanical Engineering perspective, 'Principles of Electronic Instrumentation' overemphasized material on electronics and semiconductors and underemphasized sensors and the use of instrumentation usage, both of which are very important for Mechanical Engineers. Thus, the Mechanical and Industrial Engineering Department proposed the development of a new, two s.h. course to teach sensors, instrumentation, and data acquisition using modern software (LabView). The new course, 'Engineering Instrumentation,' also allowed the sensors component to be removed from ME:4080 (58:080), 'Experimental Engineering,' providing more time to concentrate on advanced experimental techniques and

uncertainty analysis. In addition, Mechanical Engineering students now are required to take the two s.h. course ENGR:2730 (57:017), 'Computers in Engineering,' in which they learn programming, an important area that the faculty wanted to reinforce.

Fall 2011 (first offering): James Buchholz
Course description: Measurement errors and calibration, measurement circuits, laboratory instrumentation, amplifiers, frequency domain, frequency response, noise, analog filters, sensors, data acquisition, LabView, and signal processing and filtering with LabView. This is a two s.h. course, including eight two-hour laboratory sessions.

Fall 2012: James Buchholz
The curriculum was modified to de-emphasize frequency domain, frequency response, and filters; there was an increased emphasis on instrumentation, calibration, and error analysis.

Fall 2013: James Buchholz
To support a significant increase in enrollment, a second lecture section and two additional laboratory sections were established. Prof. Buchholz taught both lecture sections, and an instructor was hired to supervise the laboratory sections (reporting to and receiving support and assistance from Prof. Buchholz). The number of students in each laboratory section also was increased, requiring the purchase of equipment for the additional laboratory stations. This also provided an opportunity to replace old equipment used in the laboratories.

ME:4048 (58:048): 'Energy Systems Design'

Fall 2012: H. S. Udaykumar
ME:4048 (58:048), 'Energy Systems Design' (ESD), was taught (all lectures and discussion sessions) in the TILE classroom, which was designed to promote active-learning pedagogies and student collaboration. These classrooms are equipped with extensive technology, including large monitor displays for each student's table, large screens and projectors for viewing by the entire class, network connectivity, and microphones available at each table in the larger rooms. Students work in groups to foster peer-supported learning, and the course mainly relies on several mini-projects and a larger, end-of-semester project to enable students to learn by doing. Feedback from students has been very positive. The course structure now follows the principles of inquiry-based learning in which students self-direct their learning while the teacher acts as a facilitator.

ME:3052 (58:052), 'Mechanical Systems'

Spring 2012: Justin Garvin
Based on the results of the assessment of outcome (k) in the spring of 2011, the rubric for this outcome was modified. Explicit references to "ANSYS" and "Pro/E" were replaced by "commercial finite element program" and "solid modeling software," respectively, because students were not required to use ANSYS and Pro/E exclusively in their projects. The modified rubric was used in the spring of 2012.

Spring 2013: Hiroyuki Sugiyama
The finite element section was slightly modified specifically to provide the students with a better understanding of modeling and numerical errors in finite element solutions. Lectures on "finite element modeling and errors" were added for this purpose. This slight modification helped students evaluate numerical results obtained by finite element software in the computer project, and the average score in the discussion and evaluation sections of the project report was improved.

ME:4055 (58:055), 'Mechanical Systems Design'

Fall 2012: Hongtao Ding
This course was taught by Professor Ding who joined the Department in the fall of 2012. ME:4055 (58:055), 'Mechanical Systems Design,' which was already used to assess outcomes (f) and (m), also was used to assess outcomes (i) and (j). An introduction to modern wind turbine systems, in particular, the design of the gear box of a wind turbine, was added to help students engage in life-long learning and gain more knowledge of contemporary issues.

Fall 2013: Olesya Zhupanska
In 2013, the assessment instruments were completely redesigned. The outcome was assessed using written assignments on product liability, standards, and engineering ethics. Also, the final exam included questions to assess the students' knowledge concerning NSPE's Code of Ethics. Course topics related to product liability, standards, and engineering ethics were revised. A number of guest speakers (from industry, Law School, and the UI ADA compliance office) were invited to give lectures.

Course Revision Summary: ME:3052 (58:052), 'Mechanical Systems,' and ME:4055 (58:055), 'Mechanical Systems Design,' Spring 2013, Olesya Zhupanska

ME:3052 (58:052), 'Mechanical Systems,' is a required, junior-level course, and ME:4055 (58:055), 'Mechanical Systems Design,' is a required, senior-level course in the ME program, with the former course being a pre-requisite for the latter course. Both courses were discussed and re-evaluated at a series of the Mechanical Systems group faculty meetings in the spring of 2013. As a result of these discussions, several changes were recommended and approved by the MIE faculty in May 2013. The changes were implemented in the spring of 2014.

As a result of the revisions, many topics that were taught previously in ME:4055 (58:055), e.g., fatigue and durability in design, fracture, engineering ethics, product liability, and standards, were moved to ME:3052 (58:052), 'Mechanical Systems.'

New topics were added to the revised ME:4055 (58:055) course, i.e., kinematics of mechanisms, dynamics and vibration of machines, and computer-aided analysis of machines. Previously, these topics were not covered in any required undergraduate ME courses.

The revised course, ME:3052 (58:052), 'Mechanical Systems,' is a four s.h. course, whereas it had been a 3 s.h. course in the past. The topics that will be covered include product liability,

standards in engineering design, engineering ethics, mechanical behavior and failure of materials, materials selection in design, stress and deflection analysis, static failure theories, fatigue and durability in design, fracture, statistical and reliability considerations, and finite element analysis using commercially available software.

The revised course, ME:4055 (58:055), 'Mechanical Systems Design,' is a 3 s.h. course that had been a 4 s.h. course in the past. The topics covered include kinematics of mechanisms, dynamics and vibration of machines, design of cams and gears, design of machine elements, and computer-aided analysis of machines. The course ENGR:2710 (57:010), 'Dynamics,' was added as a pre-requisite for ME:4055 (58:055).

ME:4080 (58:080): 'Experimental Engineering'

Fall 2010 Acquisition of Skystream 3.7 Wind Turbine: Pablo M. Carrica
ME:4080 (58:080), 'Experimental Engineering,' is an experiment-based course for seniors in ME. To combine advanced experiments and content on the contemporary topic of wind energy, a Skystream 2.4 kW wind turbine was installed on campus, three blocks south of the Experimental Engineering Laboratory. The turbine was purchased with funds from the College of Engineering and a grant from the Iowa Alliance for Wind Innovation and Novel Development (IAWIND). Also, the grant allowed for the purchase of wireless data acquisition systems and instrumentation to allow students to perform remote experiments using the turbine. The turbine is equipped with a hinged tower base and a winch that enables the turbine to be lowered and raised easily.

The turbine was commissioned in 2010, and it was first used by students in the fall semester of 2010. Students use the turbine to perform experiments for the final project in ME:4080 (58:080), 'Experimental Engineering.'

Spring 2011: Pablo M. Carrica
In the spring of 2011, rubrics were developed to assess Student Outcome (b) "ability to design and conduct experiments and to analyze and interpret data," Performance Indicator "use of hardware and lab equipment" in Student Outcome (k), and Performance Indicators "organization in writing" and "writing skills" in Student Outcome (g). To accommodate the grading needed for the assessments, the individual and group reporting requirements were modified. Homework was required but not graded, and weekly quizzes were implemented to prevent students from downloading textbook solutions from the Internet.

Fall 2011: Pablo M. Carrica
Due to poor results with the quizzes, graded homework was implemented again. Some of the problems were specifically designed for the course instead of coming from the textbook.

Spring 2012: Pablo M. Carrica
Now, all homework problems are developed specifically for the course. This resulted in better performance in uncertainty analysis and dynamic response results. All experiments were revised to implement the transition to LabView software beginning in the fall of 2012.

Fall 2012: Pablo M. Carrica
The curriculum was modified in response to the implementation of 58:051, 'Engineering Instrumentation.' The elimination of Sensors, now taught in 'Engineering Instrumentation,' allowed additional time for the performance of more complex experiments, more data analysis (including uncertainty), and improved reporting. Eighty percent of the experiments were performed using LabView instead of DASYLab, and one LabView lecture was added to refresh the concepts that were taught in 'Engineering Instrumentation.' Twenty percent of the experiments still use DASYLab because the available hardware is incompatible with LabView; these experiments will be updated in the next few semesters.

Spring 2013: Hongtao Ding
Two more experiments were converted to use LabView instead of DASYLab. The remaining two experiments still using DASYLab have hardware that is incompatible with LabView, and they will be updated in the next few semesters.

Spring 2014: Pablo M. Carrica
The development of a new experiment on the reduction of vapor cavity drag reduction was initiated, and it will be introduced as a final project. The plan is to complete it and offer it as an elective experiment in the fall of 2014.

<u>Certificate in Wind Energy</u>

Spring 2013: Pablo M. Carrica
A new interdisciplinary undergraduate certificate in wind energy was developed and became effective in the spring of 2013. Wind energy has become a major source of clean energy, and the use of this technology is expected to increase over the next few decades, creating the need for professionals with diverse backgrounds and knowledge of the fundamentals of wind energy. Iowa has a strong stake in wind energy. It generates more electricity from wind than any other state in the country, and several facilities that manufacture wind turbines, towers, and blades are located in the state. The Certificate in Wind Energy integrates coursework and the faculty's expertise from the Departments of Mechanical and Industrial Engineering, Civil and Environmental Engineering, Electrical and Computer Engineering, and Geography.

Students must take 18 semester hours of coursework in any of the departments involved, and there are two required courses, i.e., IE:4550 (56:155), 'Wind Power Management,' and GEOG:3560 (44:130), 'Spatial Analyses of Wind Energy.' The other 12 semester hours are elective and can be used to complete the conditions for the EFA, as required by the Mechanical Engineering program.

Two courses are being offered this semester for the first time in the context of the Certificate in Wind Energy, i.e., ME:4142 (58:142), 'Wind Turbine Aerodynamics,' and GEOG:3560 (44:130), 'Spatial Analyses of Wind Energy,' developed in the Mechanical and Industrial Engineering and the Geography Departments, respectively.

It is expected that between 10 and 15 students will enroll to the Certificate in Wind Energy every year, attracted by the multi-disciplinary nature of the curriculum and the contemporary content of the courses offered. The Student Chapter of the American Wind Energy Association (AWEA) at the University of Iowa has dozens of affiliated students who are interested in the area of wind energy, complementing the offering of the Certificate.

4.C Additional Information

One of the major improvements of our program during this ABET review cycle relates to the method used to document and maintain ABET assessment results and continuous improvement activities. We used the online capabilities provided by ICON, which is the course management system at the University of Iowa. Most instructors in ME program use ICON as the website for their courses. We created a site on ICON called "Mechanical Engineering Program Administration." Each semester, the ME faculty upload the ABET information to this site, such as the results of the assessment of student outcomes, continuous improvement activities, and rubrics and assessment instruments. In addition, other ABET information, such as minutes of the meetings conducted by the ME program concerning ABET, also has been uploaded to the ICON site. Based on the user-friendly interface provided by ICON, the ABET information on the site is well organized by categories and subcategories.

In addition, hard copies of the materials and documentation supporting the assessment process will be available to the reviewers during the accreditation visit. The material will be organized as follows: (1) documentation and assessment results will be organized by each of the ME student outcomes and (2) documentation will be organized by course and will include the syllabus, course material, samples of students' graded work, and the results of assessments of the various courses.