Session 2793

Development and Implementation of a Course-Level Assessment Plan

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Abstract

Course-level assessment in the spirit of continuous improvement is key to successful evaluation of an engineering program. The assessment process involves stating proper educational objectives and specific course outcomes, forming performance criteria and metrics, and assessing the achievement of the stated outcomes. This paper presents the development of a course syllabus and associated performance criteria and metrics and the implementation of an assessment plan. It will go beyond EC2000 outcomes by identifying diagnostic and criterion assessment mechanisms. The assessment process will focus on the performance criteria, performance metrics, grading methods, and tracking and feedback for continuous improvement. A survey-feature of the assessment plan will be tested on a typical engineering course and an examination of how such a course would fit in the larger picture of an engineering program will be performed. Finally, this paper concludes in matching EC2000's educational outcomes (a-k) to the educational objectives of the course, maps the assessment tools of the course to Bloom's taxonomy of learning, and comments on the usefulness of an outcomes-based assessment survey.

I. Introduction

The accreditation process of engineering programs has taken a new form, becoming an outcome-based process where individual courses and experiences must contribute to the big picture of engineering education. This process has caused the majority of engineering programs around the nation to reflect on their educational focus, examine teaching and learning styles, experiment with new and innovative approaches to assess students' learning, and above all put in place an improvement process [1]. Revisiting what one teaches in a certain course and addressing what students are really getting out of the course are certainly not easy tasks. This evaluation process becomes especially difficult when a course is an integral part of a sequence of courses having an identifiable set of objectives and outcomes, tying a number of courses to each other and meeting some of the program's educational objectives. There are a number of references in the literature that focus on assessment methodologies, presenting techniques such as surveys, portfolios, entrance and exit interviews, teaching goals inventories (TGI's), and many others [2,3,4]. Recently a number of coalitions, centered around continuous improvement, were formed for the enhancement and assessment of the educational environment. Based on the experiences of the Gateway Coalition for Undergraduate Education, McGourty [5] summarized strategies for developing and implementing a comprehensive assessment plan and presented a five-step assessment process. An "Assessment Plan Development Guide," developed for the Foundation Coalition, crossed boundaries as it was adapted by Duerden and Garland [6] and applied to English classes. Johnson and Wheeler [7] presented a scheme (database) for getting detailed, assignment-level data on engineering curricula. The present paper describes the development of a course-level assessment plan, presenting performance criteria and metrics, grading and assessment methods, continuous improvement process, and tracking and feedback.

II. The Course-Level Assessment Plan

The assessment plan proposed here addresses the formulation of the following blocks:

1. EC2000 Course Syllabus: This block not only defines the format and content of the syllabus recommended by ABET but also identifies course learning objectives and makes them known to students. These are course-level objectives describing broad skills students are expected to demonstrate competency in by the end of the course.
2. Performance Criteria:
   - 2.1. Learning (Educational) Outcomes
   - 2.2. Grading/Evaluation Methods
   - 2.3. Performance Metrics and Tracking
3. Assessment Methods:
   - 3.1. Development of Assessment Methods and Instruments (Surveys)
   - 3.2. Bloom's Taxonomy of Learning
   - 3.3. Testing of Assessment Methods: Compliance with ABET's (a-k) and Additional Outcomes
4. Improvement Process and Feedback: Apply results, reevaluate and repeat for continuous improvement

It is important to note that the above blocks are not totally independent and that the assessment process is a cyclic operation.

1. EC2000 Course Syllabus:

The education literature is rich on articles for writing a proper course syllabus [4,8]. However, in light of ABET's outcomes (a – k of Criterion 3 [9]), some changes to the "Old ABET Syllabus Format" were identified. The "Old ABET Syllabus Format" consists of the following items: *Course Number, Name, and Date; Catalog Data; Textbook; References; Coordinator(s); Goals; Prerequisites by Topic; Topics; Computer Usage; Laboratory Projects; and Estimated ABET Category Content*. EC2000 proposes an outline for a "New ABET Syllabus Format", adding items such as *Course Learning Objectives and their Relationship to the Program Educational Objectives and Professional Component*. The ABET syllabus format needs to be consistent for each course and should not exceed two pages per course [10]. Appendix A contains a sample template of a new ABET syllabus for a typical engineering course, namely Thermodynamics. In developing this syllabus, the course content was revisited for the purpose of identifying course learning objectives and how and where these objectives relate to the program educational objectives. As a result, an "eye-opener" matrix was constructed exhibiting the link between the course learning objectives and the program educational objectives.

2. Performance Criteria:

In addition to the standard syllabus as recommended by the Self-Study Report of EC2000 [10] and presented in Appendix A, the faculty member must develop performance criteria and grading methods to ensure the achievement and assessment of desired outcomes. In other words, for each educational objective, a set of outcomes is generated for the purpose of stating specific activities students are expected to perform. For writing proper educational objectives, the reader is referred to Gronlund[11] and Stice[12]. The educational objectives of Thermodynamics were exhibited in Appendix A as a component of the ABET syllabus. Based on these objectives, a set of educational outcomes was constructed and is presented below. The performance criteria of the course are completed by choosing suitable grading methods (techniques for classroom assessment) and stating performance metrics.

2.1. Learning (Educational) Outcomes[b]

Objective 1: identify the thermodynamic state of any substance and demonstrate the successful retrieval of thermodynamic properties, given thermodynamic property tables

Outcomes:

1.1 Students will utilize thermodynamic property tables to correctly fix the state of any simple compressible substance [GM1, 2, 3, 4, 5].

1.2 Students will utilize ideal gas tables to correctly fix the thermodynamic state of any ideal gas [GM1, 2, 3].

1.3 Students will utilize incompressible substance approximations to correctly fix the thermodynamic state of a solid and a liquid [GM1, 2, 3].

Objective 2: identify, formulate, and solve problems in classical thermodynamics

Outcomes:

2.1 Students will demonstrate their ability to distinguish between closed and open systems, set-up a workable model of an actual thermodynamic system, and apply appropriately the first law of thermodynamics to open and closed systems [GM1, 2, 3, 4, 5].

2.2 Students will demonstrate their ability to perform entropy balance on open and closed systems [GM1, 2, 3, 4, 5].

2.3 Students will demonstrate their ability to solve problems coupling the first and second laws of thermodynamics [GM1, 2, 4, 5].

Objective 3: demonstrate the development of a systematic approach to problem solving

Outcomes:

3.1 Students will demonstrate their ability to solve problems methodically by starting with a simplified sketch of the physical system, applying appropriate assumptions, selecting a suitable theory or principle (conservation of mass, 1st law, and/or 2nd law), and computing a final result [GM1, 2, 3, 4].

3.2 Students will demonstrate their engineering judgement by reflecting on the goodness of the final result and detect possible sources of errors (if any) [GM1, 2, 3, 4, 5].

Objective 4: apply fundamental principles to the analysis of thermodynamic power and refrigeration cycles

Outcomes:

4.1 Students will exhibit their ability in applying conservation of mass, the first and second laws of thermodynamics to analyze and evaluate thermal efficiencies of simple power cycles (Rankine, Brayton, Otto, and Diesel cycles) [GM1, 2, 4, 5].

4.2 Students will exhibit their ability in applying conservation of mass, the first and second laws of thermodynamics to analyze and evaluate coefficients of performance of simple refrigeration cycles [GM1, 2, 4, 5].

Objective 5: apply fundamental principles to the design of thermodynamic systems

Outcomes:

5.1 Students will design energy systems based on their knowledge and proper application of the fundamental principles of thermodynamics [GM4, 5].

5.2 Students will function in teams and examine the impact of their designs on society and the environment [GM4, 5].

Objective 6: integrate the use of computer tools in the analysis and performance of thermodynamic systems

Outcomes

6.1 Students will make use of the Internet to further their understanding and expand their horizons in the field of thermodynamics [GM2, 4].

6.2 Students will utilize computer tools (Excel, Mathcad) to address open-ended problems and to perform parametric investigations [GM2, 4, 5].

6.3 Students will utilize computer tools (Word, PowerPoint) to present their findings on their design project and laboratory experiences effectively [GM4, 5].

b: Letters and Numbers in brackets refer to grading methods (GM's) used to assess students performance.

2.2. Grading/Evaluation Methods (GM's)

The proper use of grading methods by the professor illuminates the teaching focus and points directly to the nature of activities students are expected to conduct. Naturally, these grading methods should be made explicitly known to students. For example, the following classroom assessment techniques were identified for the Thermodynamics course.

(GM1) <u>Exams (Two)</u> = 36 %
(GM2) <u>Homework</u> = 14 %
(GM3) <u>Quizzes</u> = 10 %
(GM4) <u>Design Problem(s)</u>[computer assigs, open-ended problems, component design] = 10 %
(GM5) <u>Comprehensive Final Exam</u> = 20 %.

2.3. Performance Metrics and Tracking

Having identified the educational objectives and outcomes and grading methods for the course, two types of performance metrics are implemented and monitored:

1. Level of mastery (defined for both final exam and design project activities)
2. Indicator of student/class improvement.

The first metric addresses the achievement of the overall course educational objectives by having:

(i) 75% of students surpass the mastery level of 85/100 in the final exam, and
(ii) 80% of students surpass a mastery level of 88/100 in the design related problems/ projects.

The second metric is designed to track students' improvement by specifying that the class (on average) should show:

(i) 10% in improvement of the average grade between quizzes and related in-semester exams, and
(ii) 5% improvement (of the average grade) on the final exam when compared to that for the in-semester exams.

1. Assessment Methods:

3.1. Development of Assessment Methods and Instruments (Surveys)

In line with the grading methods outlined earlier, there are five assessment tools to be used in the course [13]:

1. Exams (In-semester, and Comprehensive Final)
2. Homework
3. Quizzes
4. Design-Related Problem(s) / Project
5. Students' Surveys (Midterm, End of course).

To assess the educational outcomes and whether or not the objectives are achieved, the assessment tools are designed to support each other. Homework assignments are intended to prepare students for the quizzes. Quizzes are designed as end of unit assessment tools, exams are designed to be end of course section, while the comprehensive final exam is designed to be end of course. Projects are designed to be end of course [14].

Two student-oriented surveys are conducted during the course. The first survey will be conducted at the midpoint of term, while the second is at the end of the course. The first is aimed at assessing the teaching style, the rate of learning, and the initial students feedback on meeting the course objectives and expectations. The feedback from this survey will allow for adjustments and improvements, which is poised for implementation in the second half of the course. The second survey will focus on assessment of the overall course, in achieving course objectives, and recommendations for future improvement [15]

The end of the course survey is tailored to capture correspondence of what was done in class to targets set by the instructor on the various outcomes. Appendix B presents the "Outcomes-Based Assessment Survey" covering ABET's (a-k) and additional outcomes addressing program specified criteria and other outcomes considered to be fundamental attributes of the program. This course survey is not a diagnostic-type survey but rather a "perception clarifier," shedding light on whether on not students and the course coordinator have the same "faith" in the course's contribution to the achievement of the program educational outcomes.

3.2. Bloom's Taxonomy of Learning

To ensure consistency between the teaching approach/focus (how and what professors provide their students) and the grading/evaluation methods, a mapping of Bloom's learning taxonomy is performed. There are six levels in Bloom's taxonomy of learning [16], and Table 1 shows which levels are addressed by the various grading methods of a typical engineering course:

1. Knowledge: (List, Recite)
2. Comprehension (Explain, Paraphrase)
3. Application (Calculate, Solve)
4. Analysis (Classify, Predict, Model, Derive, Interpret)
5. Synthesis (Propose, Create, Design, Improve)
6. Evaluation (Judge, Select, Justify, Recommend, Optimize).

Table 1. Mapping of Bloom's taxonomy of learning to assessment tools.

		Bloom's Taxonomy of Learning					
		Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
Assessment Tools	Homework	x	x	x	x		
	Quizzes		x	x	x		
	Exams		x	x	x		
	Projects		x	x	x	x	x
	Final Exam		x	x	x		

3.3. Testing of Assessment Methods: Compliance with ABET's (a-k) and Additional Outcomes

Needless to say, obtaining and maintaining accreditation is very important to a university and its associated programs. Table 2 shows how the educational objectives of Thermodynamics maps to ABET's educational outcomes (a-k) [9]. It is important to note that a single course, such as Thermodynamics, is not anticipated to match all of ABET's outcomes, while the outcomes of all courses of an engineering program must do collectively. Table 2 features additional program outcomes. The complete list of program outcomes (a-s) can be found in Appendix B.

Table 2. Correspondence between Thermodynamics educational objectives and ABET's (a - k).

Course Objectives	**Program Outcomes: ABET's Outcomes (a – k) and Additional Outcomes**																		
	a	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**	**o**	**p**	**q**	**r**	**s**
δ.1	x				x							x							
δ.2	x				x				x		x	x	x			x			
δ.3	x				x		x												
δ.4	x	x			x		x				x	x	x			x			
δ.5	x	x	x	x	x	x	x	x	x		x	x	x			x			
δ.6	x				x		x		x		x	x	x						

One hundred students enrolled in the course Thermodynamics (four different sections taught by three different professors) were encouraged to take the "Outcomes-Based Assessment Survey" and seventy three responded to the call. Figure 1 shows students' perceptions of to what level this course contribution in helping them in achieving the nineteen outcomes stated for the program. Also plotted on the same figure, the course coordinator's perception of the expected level of achieving the same outcomes.

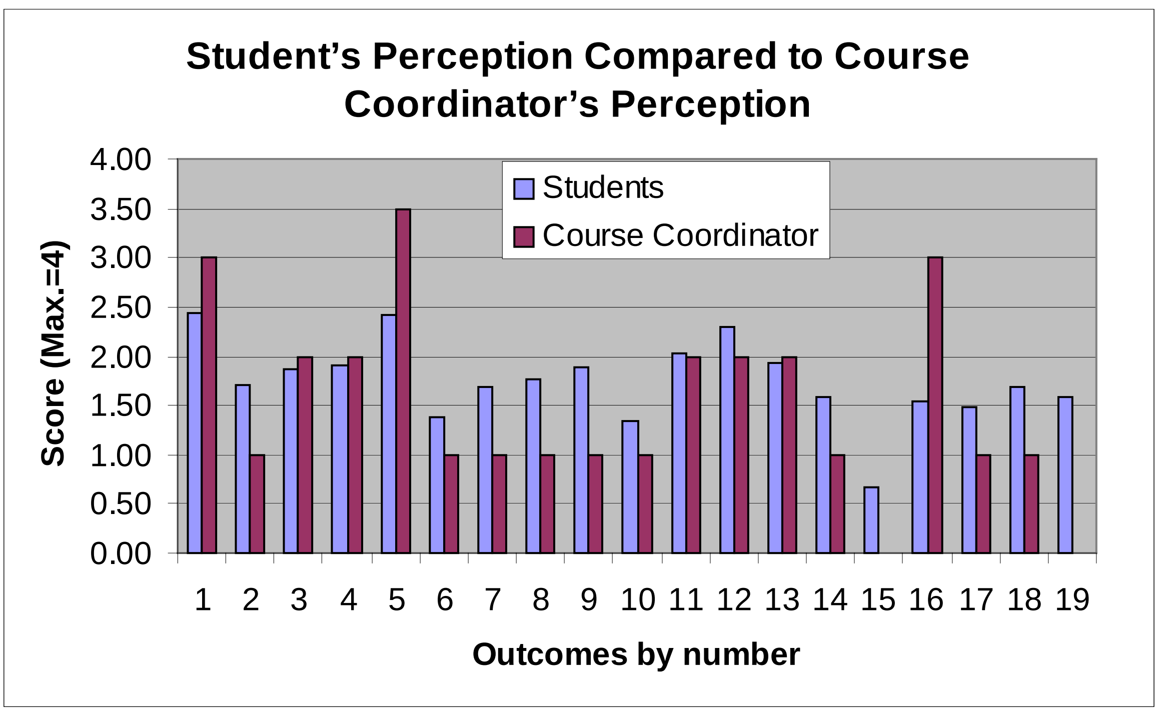

Figure 1. Comparison of students' perception to those of the course coordinator.

4. Improvement Process and Feedback:

Examining Figure 1, one realizes that outcomes 11 (k) and 13 (m) are essentially the same and students indeed responded to them via the same perception. For a course such as Thermodynamics, the major focus is on problem solving and applying the laws of physics and nature. Indeed of the nineteen outcomes (a – s), the course coordinator feels strongly about this course's contribution in meeting outcomes 1 (a) and 5 (e). Students agreed although falling short on the intended level of contribution. What should one do about students perception falling short of that of the coordinator? It is recommended that:

1. more than one run of surveys be conducted, at least three times over a period of a year. Conducting the survey more than one time should yield a constant gauge of students' responses and will help in eliminating variability.
2. course coordinators reexamine the alignment of course learning objectives and outcomes to the program outcomes since all survey results will be compared to the intended ratings set by the course coordinator. The challenge remains in having the individual professors teaching the various sections follow the same syllabus and focus on the same educational objectives.
3. professors have a uniform story encouraging their students to take the survey. Tell students what this survey is for, show believability in it, and encourage (via percentage points as extra credit) all to take it. The more students that take the survey the better. All students in the class should take the survey. Students needing extra credit can possibly sway the results of the survey. The importance of this point can be seen upon reflecting on who really participated in taking the survey (i.e. those needing extra credit actually took it or otherwise).
4. students perception be tested for consistency. Consistency of students perception can be verified by comparing results from different sections taught by the same professor (assuming the same teaching approach/focus is used by the professor across different sections).
5. this survey not be used as a tool to determine if individual professors are doing what they are supposed to. An undesirable effect would be to have the professors feel negatively about the survey. Professors might feel threatened and might want to hide behind the wall of academic freedom. After all, the goal here is continuous improvement and that starts with the professors.
6. another assessment technique, a diagnostic tool (based on the grading methods, assessment tools and performance metrics), be carried out before a change is recommended, since this survey is not a diagnostic tool.

III. Conclusions

This paper presented the development and application of an assessment plan in the spirit of continuous improvement. In generating a common syllabus for a typical engineering course, the authors reflected on the educational objectives and outcomes of the course. The learning objectives are statements that can be observable and measurable, and the outcomes are reflections of the professor's expectations and are items demonstrating students' ability and learning. The paper extended on the elements of a typical EC2000 syllabus by presenting sample assessment mechanisms. The assessment process focused on performance criteria, performance metrics, grading methods, improvement process, and tracking and feedback. The paper also presented a map between the assessment tools and Bloom's taxonomy of learning and a map between course educational objectives and program outcomes. It concludes with testing an outcomes-based assessment survey and points out a list of recommended actions. The outcomes-based assessment survey should be used in conjunction with diagnostic tools to ensure that a change is needed and that this change produces desired results.

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Dr. Alzahabi is an assistant professor at Kettering University (formerly GMI Engineering & Management Institute). His areas of expertise are Engineering Solid Mechanics and Computer Aided Engineering. His current activities involve the development of new undergraduate Integrated Engineering Mechanics sequence, Curriculum assessment, and teaching courses in Mechanical Vibration, Finite Element Analysis, Vehicle Design Project, and Automotive Noise, Vibration and Harshness.

Appendix A: Syllabus Template

ME-304, Thermodynamics
Syllabus --- Summer Term 2001

2000-01Catalog Data: ME-304 Thermodynamics
Credit: 4 (4-0-4)

Prerequisites: PHYS-220 Physics II: Electromagnetism
Corequisites: None
Description: A study of the first and second laws of thermodynamics and their application to energy transformations during various processes. Property relations are studied for pure substances, ideal gases, mixtures of ideal gases, and atmospheric air. Steam power cycles, refrigeration cycles, spark-ignition and compression-ignition engines, and turbine cycles are evaluated to determine performance parameters and energy efficiencies.

Textbook: Moran and Shapiro, *Fundamentals of Engineering Thermodynamics*, 4th Edition, John Wiley & Sons, 2000.

References: Van Wylen, G., Sontag, R., and Borgnakke, C., *Fundamentals of Classical Thermodynamics*, 4th Edition, John Wiley & Sons, 1994.

Coordinator(s): Karim J. Nasr, Room 1-937 AB, 762-7876, knasr@kettering.edu
Office Hours: Open Door Policy & MRF = 10:00-11:00 am

Course Learning Objectives (δ)[a]:

Upon completion of this course, "Thermodynamics", the student will be able to:

δ.1. identify the thermodynamic state of any substance and demonstrate the successful retrieval of thermodynamic properties, given thermodynamic property tables [α.1].

δ.2. identify, formulate, and solve problems in classical thermodynamics [α.1, α.3, α.4].

δ.3. demonstrate the development of a systematic approach to problem solving [α.1, α.2, α.3].

δ.4. apply fundamental principles to the analysis of thermodynamic power and refrigeration cycles [α.1, α.2, α.3].

δ.5. apply fundamental principles to the design of thermodynamic systems [α.1, α.2, α.3, α.4].

δ.6. integrate the use of computer tools in the analysis and performance of thermodynamic systems [α.1, α.3, α.4, α.5].

a: Greek Letters in brackets refer to Kettering's ME Program Educational Objectives (α's).

Relationship of Course Learning Objectives to Program Educational Objectives:

Matrix A shows the relationship between the above course learning objectives and the educational objectives of the ME program. The educational objectives of the Mechanical Engineering program at Kettering University state that the Department of Mechanical Engineering produces graduates who:

α.1 are knowledgeable in the management and use of modern problem solving and design methodologies.

α.2 understand the implications of design decisions in the global engineering marketplace.

α.3 are able to formulate and analyze problems, think creatively, communicate effectively, synthesize information, and work collaboratively.

α.4 have an appreciation and an enthusiasm for life-long learning.

α.5 actively engage in the science of improvement through quality driven processes.

α.6 practice in the field of Mechanical Engineering professionally and ethically.

α.7 are prepared for positions of leadership in business and in industry.

Matrix A: Thermodynamics course learning objectives (δ's) vs. Mechanical Engineering Program educational objectives (α's)

Course Learning Objectives	M.E. Program Educational Objectives							
		α.1	α.2	α.3	α.4	α.5	α.6	α.7
	δ.1	x						
	δ.2	x		x	x			
	δ.3	x	x	x				
	δ.4	x	x	x				
	δ.5	x	x	x	x			
	δ.6	x		x	x	x		

Prerequisites by Topic:
(1) Partial Derivatives
(2) Concepts of Work & Power
(3) Basic Computer Skills (MS Word, Excel, and Mathcad)

Topics Covered:

Week	*Topic*
1	Introduction, Energy and Work, Heat
2	1st Law of Thermodynamics, Energy Balance- Closed systems, Cycle Analysis
3	Properties: phase diagrams, Tables look-up, Ideal Gas
4	Closed system example with properties (Otto Cycle) Conservation of Mass, Conservation of Energy, SSSF
5	Conservation of Energy, (cont.): SSSF, Rankine cycle, USUF
6	Second Law: Thermal Reservoir, Clausius statements, Kelvin-Planck statement, Irreversible and reversible processes, Kelvin temperature scale
7	Second Law, (cont.): Maximum efficiency/performance, Carnot cycle Entropy: Clausius Inequality, T-ds equations, ideal gas solids
8	Entropy retrieval, 2nd Law, closed system, 2nd Law, open system. Isentropic processes
9	Cycles: Rankine Cycle, Air-Standard Introduction
10	Cycles, (cont.): Otto Cycle, Diesel Cycle, Air Standard Brayton Cycle Vapor-Compression Refrigeration Cycle
11	Comprehensive Final Examination

Computer Usage:
Basic Computer Skills (MS Word, Excel, and Mathcad)
Class/Laboratory Schedule:
Two sessions per week, each is 2-hr long. No required laboratory experiences.
Relationship to Professional Component:
This course is 25% Basic Science and 75% Engineering

Prepared by: Karim J. Nasr, Associate Professor of Mechanical Engineering. 1/1/00.

Appendix B: Outcomes-Based Assessment Survey

Recognizing that each course has its own learning objectives and outcomes, please rate the contribution of THIS COURSE in meeting the M.E. Program educational outcomes:

1. Ability to apply knowledge of mathematics, science and engineering.	A	B	C	D	E
2. Ability to design and conduct experiments, as well as to analyze and interpret data.	A	B	C	D	E
3. Ability to design a system, component, or process to meet desired needs.	A	B	C	D	E
4. Ability to function in multidisciplinary teams.	A	B	C	D	E
5. Ability to identify, formulate and solve engineering problems.	A	B	C	D	E
6. Understanding of professional and ethical responsibility.	A	B	C	D	E
7. Ability to communicate effectively.	A	B	C	D	E
8. Broad education that is necessary for understanding the impact of engineering solutions in a global and societal environment.	A	B	C	D	E
9. Recognition of the need for engaging in life-long learning activities.	A	B	C	D	E
10. Knowledge of contemporary issues.	A	B	C	D	E
11. Ability to use the techniques, skills and modern engineering tools necessary to perform effectively in an engineering setting.	A	B	C	D	E
12. Ability to work professionally in both thermal and mechanical systems areas including the design and realization of such systems.	A	B	C	D	E
13. Competence in the use of computational mathematics tools germane to the world of engineering.	A	B	C	D	E
14. Competence in experimental design, automatic data acquisition, data analysis, data reduction, and data presentation, both orally and in the written form.	A	B	C	D	E
15. Competence in the use of computer graphics for design communication and visualization.	A	B	C	D	E
16. Knowledge of chemistry and calculus based physics	A	B	C	D	E
17. Ability to manage engineering projects including the analysis of economic factors and their impact on the design.	A	B	C	D	E
18. Ability to understand the dynamics of people both in a singular and group setting.	A	B	C	D	E
19. Competence in the analysis of inter-disciplinary mechanical/hydraulic systems.	A	B	C	D	E

A = High Contribution, B = Above Average, C = Average, D = Below Average, and E = Not Applicable.