2006-831: CONTENT ASSESSMENT AT THE COURSE LEVEL

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Content Assessment at the Course Level

Abstract

The Accreditation Board for Engineering and Technology has increased the awareness of engineering educators for the need to assess student learning. Much of the effort associated with the accreditation process is focused on direct measurements of student learning related to program outcomes. This paper presents a proposal for assessing course content using student surveys (an indirect measure) to determine the students' opinions on their preparation for the course (Were prerequisites adequate?), their understanding of the material associated with the learning objectives of the course, and their increased abilities in program outcomes which are specifically addressed in the course. Example survey instruments and example compiled results are displayed and discussed. It is proposed that the results from such course level surveys can be useful input to a comprehensive program assessment.

Introduction

The whole may be or may not be greater than the sum of its parts. However, when the whole is found lacking, it may be difficult to identify the missing or faulty parts. So it may be with the assessment process associated with Accreditation Board for Engineering and Technology[1] (ABET) accreditation. Direct assessment of learning is determined through standardized testing and other independent evaluating procedures to quantify student learning related to program outcomes. Two-year and five-year out alumni and alumna are asked if they have been able to maintain (or change if desired) their professional employment or be accepted for graduate school, if desired. Employers are asked if their employees are performing satisfactorily and if they are continuing to progress (have an understanding of the need for life long learning). Student surveys provide indirect assessments of learning. Graduating engineering students are asked if they are able to design a component to meet desired needs or able to communicate effectively. However, effective programmatic responses to the replies to these questions may be difficult unless we can point to the specific course or courses responsible for any deficiencies. It may also be too late if, for example, an understanding of professional and ethical responsibility was supposed to be addressed in a sophomore design course taken four or more years ago by the student responding to a survey. Therefore as part of a comprehensive assessment program (which includes feedback from all our constituents), our Department has instituted a course-by-course assessment process. On a rotating basis (so as not to overwhelm the students) all undergraduate courses in the Department are surveyed every two years. In this survey students are asked to provide their feedback:

- I feel that I understand (or am able to) … (The Learning Objectives of the course are listed.)
- I feel that I have improved my ability or knowledge in… (The Departmental Program Outcomes are listed.)
- My understanding of the… (The Prerequisites for the course by topic are listed.)…was adequate preparation for this course.

There is, of course, a different survey instrument for each course, and the information used to develop each survey is obtained from the ABET formatted course syllabi prepared by the faculty or committee responsible for the course. The information obtained from these surveys can be immediately fed back into the system and corrective measures instituted even before the next semester begins, e.g., remind a new faculty member or lecturer to follow the syllabus, expand or improve course material in some areas, or request changes or better monitoring in prerequisite courses. Students are also asked to provide any other information or to make comments. The surveys are anonymous and do not replace the college administered teaching evaluations given every semester in every course. This paper contains details on the process, example survey instruments, examples of results, and examples of how actions could be implemented as well as suggestions for how the responses can be used as part of a comprehensive assessment process for Program Outcomes and ABET EC-2000 Criterion 3. Descriptions of similar processes for mechanical engineering programs [2,3], engineering programs [4] and technology programs[5-7] have been previously described in the literature.

ABET Course Syllabi

Periodically the "official" course syllabi for all undergraduate courses are reviewed by the faculty currently teaching the courses, the topic area coordinators concerned, and the Department's Undergraduate Academic Affairs Committee. Electronic and hard copies are maintained on file. This activity is the starting point for the course assessment process. An example syllabus is shown in Table 1.

The Course Surveys and Example Results

Based on the syllabi for the courses, surveys were prepared for all the required undergraduate courses and some of the electives. Table 2 presents the survey for Heat Transfer. As a test in the first year, the appropriate surveys were distributed to the instructors of all the undergraduate courses. We are now in a two-year cycle in which approximately one-fourth of the courses are surveyed each full semester (fall and spring). The surveys are completed by the students during the last week of class or during the final exam period and then the completed surveys are returned to the Undergraduate Academic Affairs Committee for processing. The results are tabulated for each course and then made ready for review. The individual comments are transcribed and returned with the tabulated results to the instructor after review. Table 3 presents an example of the tabulated results for Heat Transfer. Our goal is to achieve at least a "4" in each category and consequently a "4.1" for the average in each section: Course Learning Objectives, Departmental Program Outcomes, and Course Prerequisites. The tabulated results provide a convenient way to review at least the students' opinions about what they think they have learned. A better example of this point is seen in the results for a compiled survey for statics as seen in Table 4. The low averages for the Course Learning Objectives, Departmental Program Outcomes, and the students' lack of confidence to advance are apparent. It is also clear which course's Learning Objectives were not met. Therefore the instructor receives meaningful and specific feedback from the students about the specific weakness of the course.

Table 1: Example Syllabus for Heat Transfer

2003-2005 Catalog Data:

MECE 4364: Heat Transfer, Cr. 3 (3-0). Prerequisites: MECE 3334, 3363, and 3370. Steady and unsteady heat conduction; heat transfer by forced and free convection, radiation, and phase change; numerical solutions and heat transfer systems synthesis, design problems.

Textbook: *Heat Transfer*, 2th ed., A. F. Mills,

Prerequisites by Topic:

1. Mathematics through ordinary and partial differential equations.
2. Solutions of engineering problems by numerical analysis.
3. Dimensions and unit systems.
4. Thermodynamics and fluid mechanics.

Topics: (each class is 80 minutes, two classes per week)

1. Review of concepts of thermodynamics, differential equations, dimensions and unit systems. Scope of course and introduction to the physics of the modes of heat transfer. An overview of thermal-fluid systems and their importance to society (2 classes)
2. Heat conduction in one dimension, radiation, heat convection, combined modes of heat transfer and electrical analogies. (1 class)
3. Introduction to heat exchangers. Effectiveness and NTU concepts. Single stream heat exchangers. (1 class)
4. One-dimensional heat conduction in planar and cylindrical geometries. Internal heat generation. (1 class)
5. Fins and fin optimization. (2 classes)
6. Multidimensional heat conduction. Numerical solutions. (3 classes).
7. Lumped capacity systems. Unsteady heat conduction in slabs cylinders and spheres. Product solutions. Numerical solutions (3 classes).
8. Equations of motion and energy. Reduction to boundary layer equations. Integral solutions (2 classes)
9. Forced convection in external and internal flows. Natural convection. Boundary layers. Viscous dissipation. (4 classes)
10. Thermal radiation. Planck's and Wien's laws. Thermal exchange between black and/or gray surfaces, solar radiation, greenhouse effects. (3 classes)
11. Heat Exchangers. Counterflow, parallel flow and crossflow examples. Design issues. (2 classes)
12. Tests/Reviews - (3 classes).

Course Learning Objectives and their Relationship to Program Outcomes [1] :

1. Students will understand the phenomena of heat conduction and be able to analyze problems in one dimensional heat conduction with and without internal heat generation. (a, e, k)
2. Students will understand how to solve elementary steady and unsteady heat conduction problems in two and three dimensions and appreciate how numerical solutions can be used in complex geometries. (a, e, k)
3. Students will know how boundary layer theory plays a role in understanding the mechanisms of heat convection and be able to determine the heat transferred in a variety of classical geometries for forced and natural convection (a, e, k)
4. Students will be able to solve elementary problems in radiative exchange. (a, e, k)
5. Students will be able to solve problems where convection, conduction and radiation interact in simple geometries. (a, e, k)

Table 1: Example Syllabus for Heat Transfer (continued)

6. Students will be able to analysis and design simple thermal/fluids systems to produce a desired result, e.g., power and air conditioning systems and simple heat exchangers satisfying elementary constraints. (a, c, e, k)
7. Students will have an appreciation for the potential consequences of their actions or inactions in a technology dominated world. (h, j)

Evaluation:

1. Weekly homework assignments
2. Three open and closed book exams
3. One open and closed book final exam
4. Periodically assigned open ended, design problems which are turned in at the end of the semester.

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[1] Lower case letter in ( ) refer to Department's Undergraduate Program Outcomes (which mirror the ABET Criterion 3, i.e., criteria a through k.)

The Department's Undergraduate Program Outcomes expect all graduates receiving the BSME degree to have:

a. an ability to apply knowledge of mathematics, science, and engineering;
b. an ability to design and conduct experiments, as well as to analyze and interpret data;
c. an ability to design a system, component, or process to meet desired needs;
d. an ability to function on multi-disciplinary teams;
e. an ability to identify, formulate, and solve engineering problems;
f. an understanding of professional and ethical responsibility;
g. an ability to communicate effectively;
h. the broad education necessary to understand the impact of engineering solutions in a global and societal context;
i. a recognition of the need for, and the ability to engage in, life-long learning;
j. a knowledge of contemporary issues, especially those related to mechanical engineering;
k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Assessment of ABET EC-2000 Criterion 3

The ABET EC-2000 assessment process[1] has shifted the assessment process from "teaching" to "learning" and from "courses" to "outcomes". Therefore programs must demonstrate that their Program Outcomes are being assessed and their goals met, and that student learning is measured directly, not by student self-assessment. Outcomes can be assessed at the "program level", i.e., standardized testing such as the Fundamental of Engineering Exam, (as long as success for each Program Outcome can be separated out of the results) or it can be pursued at the "course level". The rest of this paper will be concerned with assessment at the course level and will describe how one might organize a plan for such assessment.

Table 2: Example Survey for Heat Transfer

Please indicate your level of agreement with the following statements: use 5 for strongly agree; 4 for agree; 3 for neutral; 2 for disagree; and 1 for strongly disagree.

disagree 1	2	3	4	agree 5	**I feel that I**
☐	☐	☐	☐	☐	understand the physics of the modes of heat transfer
☐	☐	☐	☐	☐	understand heat conduction in one dimension and electrical analogies
☐	☐	☐	☐	☐	am able to analyze heat exchangers using the LMTD and NTU methods
☐	☐	☐	☐	☐	am able to analyze one dimensional conduction problems in non-planar geometries
☐	☐	☐	☐	☐	am able to analyze fins
☐	☐	☐	☐	☐	am able to solve multidimensional heat conduction problems
☐	☐	☐	☐	☐	am able to solve unsteady heat conduction in slabs, cylinders and spheres
☐	☐	☐	☐	☐	understand boundary layer analysis
☐	☐	☐	☐	☐	am able to apply numerical methods to multidimensional steady state conduction problems
☐	☐	☐	☐	☐	am able to solve problems involving forced convection over a flat plate and cylinder
☐	☐	☐	☐	☐	am able to solve problems involving forced convection inside a pipe
☐	☐	☐	☐	☐	am able to solve problems involving natural convection on vertical and horizontal surfaces
☐	☐	☐	☐	☐	understand the phenomena of radiation heat transfer including Planck's distibution function
☐	☐	☐	☐	☐	am able to solve problems involving radiative exchange between black and/or gray surfaces in simple geometries
☐	☐	☐	☐	☐	am able to solve problems where conduction, convection and radiation interact in simple geometries
☐	☐	☐	☐	☐	have a good overall understanding of solving problems involving heat transfer
					I feel that this course has
☐	☐	☐	☐	☐	improved my ability to apply knowledge of mathematics, science, and engineering
☐	☐	☐	☐	☐	improved my ability to design a thermal system and component to meet desired needs
☐	☐	☐	☐	☐	improved my ability to identify, formulate, and solve engineering thermal problems
☐	☐	☐	☐	☐	improved my ability to use the techniques, skills, and modern engineering tools necessary for engineering practice,
☐	☐	☐	☐	☐	improved my knowledge of contemporary issues related to thermal/fluids issues
☐	☐	☐	☐	☐	improved my understanding of the impact of engineering solutions in a global and societal context.
					My understanding of the following subjects was adequate preparation for this course:
☐	☐	☐	☐	☐	ordinary differential equations
☐	☐	☐	☐	☐	partial differential equations
☐	☐	☐	☐	☐	solutions of engineering problems by numerical analysis
☐	☐	☐	☐	☐	dimensions and unit systems
☐	☐	☐	☐	☐	thermodynamics
☐	☐	☐	☐	☐	fluid mechanics
☐	☐	☐	☐	☐	I feel that I am prepared for Thermal-Fluids Lab. If not, please explain why not

____

____

Any Comments about the course would be appreciated: (Use the back of the page if necessary.)

____

Thanks for your help!

Table 3: Example Compiled Results for Heat Transfer

Please indicate your level of agreement with the following statements: use 5 for strongly agree; 4 for agree; 3 for neutral; 2 for disagree; and 1 for strongly disagree.

Course Learning Objectives

1	2	3	4	5	N	mean	σ	I feel that I
			10	9	19	**4.47**	0.50	understand the physics of the modes of heat transfer
			7	12	19	**4.63**	0.48	understand heat conduction in one dimension and electrical analogies
		2	9	8	19	**4.32**	0.65	am able to analyze heat exchangers using the LMTD and NTU methods
		5	7	7	19	**4.11**	0.79	am able to analyze one dimensional conduction problems in non-planar geometries
	1	6	8	4	19	**3.79**	0.83	am able to analyze fins
	1	6	9	3	19	**3.74**	0.78	am able to solve multidimensional heat conduction problems
	1	5	8	5	19	**3.89**	0.85	am able to solve unsteady heat conduction in slabs, cylinders and spheres
		2	8	9	19	**4.37**	0.67	understand boundary layer analysis
		6	8	5	19	**3.95**	0.76	am able to apply numerical methods to multidimensional steady state conduction problems
			10	9	19	**4.47**	0.50	am able to solve problems involving forced convection over a flat plate and cylinder
			9	10	19	**4.53**	0.50	am able to solve problems involving forced convection inside a pipe
		3	7	9	19	**4.32**	0.73	am able to solve problems involving natural convection on vertical and horizontal surfaces
	1	4	9	5	19	**3.95**	0.83	understand the phenomena of radiation heat transfer including Planck's distibution function
		3	8	8	19	**4.26**	0.71	am able to solve problems involving radiative exchange between black and/or gray surfaces in simple geometries
		7	7	5	19	**3.89**	0.79	am able to solve problems where conduction, convection and radiation interact in simple geometries
		1	12	6	19	**4.26**	0.55	have a good overall understanding of solving problems involving heat transfer
					Avg.	**4.18**		
					Std Dev	**0.29**		

Departmental Program Outcomes

1	2	3	4	5	N	mean	σ	I feel that this course has
		1	11	7	19	**4.32**	0.57	improved my ability to apply knowledge of mathematics, science, and engineering
	1	3	11	4	19	**3.95**	0.76	improved my ability to design a system, component, or process to meet desired needs
		4	10	5	19	**4.05**	0.69	improved my ability to identify, formulate, and solve engineering problems
	1	4	11	3	19	**3.84**	0.74	improved my ability to use the techniques, skills, and modern engineering tools necessary for engineering practice
1		4	11	3	19	**3.79**	0.89	improved my knowledge of contemporary issues related to thermal/fluids issues
	1	6	9	2	18	**3.67**	0.75	improved my understanding of the impact of engineering solutions in a global and societal context.
					Avg.	**3.94**		
					Std Dev	**0.23**		

Course Prerequisites

1	2	3	4	5	N	mean	σ	My understanding of the following subjects was adequate preparation for this course:
	1	3	8	7	19	**4.11**	0.85	ordinary differential equations
	1	4	8	6	19	**4.00**	0.86	partial differential equations
1	3		10	5	19	**3.79**	1.15	solutions of engineering problems by numerical analysis
		1	6	12	19	**4.58**	0.59	dimensions and unit systems
	1	1	10	7	19	**4.21**	0.77	thermodynamics
		2	10	7	19	**4.26**	0.64	fluid mechanics
					Avg.	**4.16**		
					Std Dev	**0.27**		

Table 4: Example Compiled Results for Statics

Please indicate your level of agreement with the following statements: use 5 for strongly agree; 4 for agree; 3 for neutral; 2 for disagree; and 1 for strongly disagree.

Course Learning Objectives

1	2	3	4	5	N	mean	σ	I feel that I understand
			11	12	23	**4.52**	0.50	and am able to use Newton's laws, force triangles and force polygons.
			6	17	23	**4.74**	0.44	and am able to perform addition and substraction of vectors and vector operations.
			10	13	23	**4.57**	0.50	equilibrium of a particle.
	1	3	11	8	23	**4.13**	0.80	force systems for rigid bodies and equivalent force systems.
	1	3	8	11	23	**4.26**	0.85	and am able to construct free body diagrams.
	2	3	10	8	23	**4.04**	0.91	and am able to calcuate the moment of a force, couples and resultants.
	1	6	8	8	23	**4.00**	0.88	equilibium of forces in two and three dimensions.
9	3	7	4		23	**2.26**	1.15	centroids, distributed loads and fluid statics.
2	4	7	6	4	23	**3.26**	1.19	and am able to analysis trusses, frames and machines.
1	4	7	9	2	23	**3.30**	1.00	internal forces and shear and bending moment equations.
2	2	10	6	3	23	**3.26**	1.07	and am able to construct shear and bending moment diagrams.
6	5	8	4		23	**2.43**	1.06	friction, wedges, cables and bearings.
12	4	4	2	1	23	**1.96**	1.20	and am able to calculate second moments of areas and mass. moments of inertia.
					avg.	**3.60**		
					st dev	**0.93**		

Departmental Program Outcomes

1	2	3	4	5	N	mean	σ	I feel that this course has
		9	11	3	23	**3.74**	0.67	improved my ability to apply knowledge of mathematics, science, and engineering.
	3	5	12	3	23	**3.65**	0.87	improved my ability to identify, formulate, and solve engineering problems.
2	3	12	4	2	23	**3.04**	1.00	improved my ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
					avg	**3.48**		
					st dev	**0.38**		

Course Prerequisites

1	2	3	4	5	N	mean	σ	My understanding of the following subjects was adequate preparation for this course:
	1	5	8	9	23	**4.09**	0.88	systems of units (SI and English)
		3	12	8	23	**4.22**	0.66	introduction to Newton's laws
		8	9	6	23	**3.91**	0.78	differential calculus
		6	12	5	23	**3.96**	0.69	integral calculus
					avg	**4.04**		
					st dev	**0.14**		
	3	12	6	2	23	**3.30**	0.80	I feel that I am prepared for MECE 3369 (mechanics of solids) and MECE 3336 (dynamics)

As noted above, course surveys such as the ones already described in this document are not sufficient to demonstrate learning. Once it has been determined which Outcomes are to be assessed in which course, the next step is to determine exactly what type of assignments will be used to directly assess student learning related to these designated outcomes. Possibilities include specific homework assignments or problems, projects, laboratory experiments, design artifacts, or specific exam questions or problems. Separate grading records and graded examples of student work should be kept for the assignments or parts of the assignment related to each designated Program Outcome. When possible these assignments should be viewed as tests for minimum competency, and students should be required to redo unsatisfactory work. It still remains to be determined which courses are to be used to assess which Program Outcomes, an issue to be addressed now.

Results from the course surveys can be used in helping to organize the Program Outcome assessment process. Table 5 represents a summary of the course survey results for our Department's courses required for the BSME program. Not all Program Outcomes need to be addressed in every course; rather, certain courses "naturally" tend to support some Program Outcomes but not necessarily others, e.g., the laboratory courses address "design and conduct experiments", "function on teams", "use of modern engineering tool", and "technical communication." One approach to this assessment process is to monitor student learning with respect to specific Program Outcomes in specific courses, e.g., the three to five courses in which a specific Program Outcome is stressed. To examine this idea further, columns four and five in Table 5 are expanded and shown in Table 6.

The Program Outcomes as defined for each class may originally have been determined by the instructor or area committee, independent of the overall program assessment process. Most faculty probably selected the outcomes for their courses based on what they had always done in their courses, not on what would be a reasonable expectation for their course and certainly not on the program's current objective of addressing each Program Outcome in at least four or five courses. In Table 6, we can see that the number of Program Outcomes addressed in each class varies from three to nine (column 3). Individual student ratings for ranged from the low-twos to the mid-fours. (Note that only the averages for all students in the class and all outcomes assigned to that class are shown in Table 6.) As noted, we would like to see a minimum of 4.0 in each. Also, it is clear that some Program Outcomes naturally associate with certain types of classes. With these two facts (student ratings and the natural association between Program Outcomes and class type) in mind between one and six Program Outcomes have been identified as the focused outcomes for each class (column 4 in Table 6). From Table 6 we can plot the focused outcomes against the courses as displayed in Table 7.

The issue is now which courses to use for the assessment of each of the Program Outcomes. The number of courses in which a particular outcome is addressed ranges from 1 to 12. Some courses are addressing as many as six outcomes. Let's attempt to reduce both these numbers, 12 and 6, to five, if possible. The outlined boxes in Table 7 indicate the outcome/course pairs selected to be maintained which reduces all the sums to five or less (except one). Now we must address the issue that four of the outcomes are addressed in only three or less courses and two, in only one course. At this point we may wish to change the content of selected courses or consider new courses. Perhaps a combination of the two is best. In our particular case we had some flexibility. Our freshman course, Introduction to Mechanical Engineering, has not previously been considered. The College of Engineering has just begun to offer a new technical communications course which was quickly approved as a "University Core Intensive Writing Elective" and just as quickly has been approved by the Mechanical Engineering Department as a new requirement for the BSME program. There had also been some discussion about offering a

Table 5: Example Summary of Survey Results for our BSME Program

Course no.*	name	Number of Learning Objectives	Course Learning Objectives Satisfied	Number of Program Outcomes Claimed	Program Outcomes Satisfied	Prerequistes were Adequate
2334	Thermo I	14	3.97	3	4.06	4.04
2336	Statics	11	3.60	3	3.97	4.04
2361	Intro to Design	4	4.22	9	4.10	
				top 3	4.27	
3334	Thermo II	7	3.37	4	3.37	3.52
				top 3	3.45	
3336	Dynamics	14	3.67	3	3.96	4.03
3338	Controls	13	4.24	7	3.84	3.91
				top 3	4.33	
3360	Measurements	16	4.27	9	4.25	4.25
				top 3	4.40	
3363	Fluids Mechanics	15	3.82	4	2.66	3.89
				top 3	2.69	
3369	Solid Mechanics	9	3.89	4	4.26	4.05
				top 3	4.28	
3445	Materials Science (with laboratory)	12	3.98	7	3.66	3.99
				top 3	3.82	
4332	FEA	7	3.98	7	3.94	3.85
				top 3	4.17	
4364	Heat Transfer	16	3.87	4	3.90	4.04
				top 3	3.97	
4371	Thermo/Fluids Lab	13	4.28	7	4.26	4.23
				top 3	4.47	
4372	Vib/Controls Lab	12	4.07	7	4.21	3.94
				top 3	4.42	
4334	Capstone Design	4	4.10	8	4.08	
				top 3	4.33	
	Averages		**3.96**	all	**3.90**	**3.98**
				top 3	**4.04**	

* The first number represents the year in which the course is usually taken (2=sophomore, etc.). The second number is the credit hours earned in a 129-hour program.

Table 6: Example Summary of Outcomes by Course

Course no.	name	# of Outcomes Claimed	Outcomes*	Student Rating	averages
2334	Thermo I	3	a, e, k	4.24; 4.17; 3.79	4.06
		focused on	a, e	4.24; 4.17	4.21
2336	Statics	3	a, e, k	4.03; 4.00; 3.87	3.97
		focused on	a, e	4.03; 4.00	4.02
2361	Intro to Design	9	a, c, d, e, f, g, h, I, j	3.77; 4.29; 4.35; 4.04; 4.18; 4.07; 4.18; 4.14; 3.86	4.10
		focused on	c, d, f, g, h, j	4.29; 4.35; 4.18; 4.07, 4.18; 3.86	4.15
3334	Thermo II	4	a,c,e,k	3.63; 3.11; 3.51; 3.24	3.37
		focused on	c,e,k	3.11; 3.51; 3.24	3.29
3336	Dynamics	3	a,e,k	4.06; 4.00; 3.82	3.96
		focused on	a,e,k	4.06; 4.00	4.03
3338	Controls	7	a,c,d, e, g, j,k	4.57; 4.26; 3.35; 4.17; 3.35; 3.00; 4.17	3.84
		focused on	a,c, e, k	4.57; 4.26;4.17; 4.17	4.29
3360	Measurements	9	a,b,c,d,e,f,g,I,k	4.41; 4.48; 3.89; 4.26; 4.15; 4.07; 4.30; 4.33; 4.30	4.25
		focused on	a,b,d,g,I,k	4.41; 4.48; 4.26; 4.30, 4.33; 4.30	4.35
3363	Fluids Mechanics	4	a,b,e,k	3.00; 2.58; 2.65; 2.44	2.66
		focused on	e	2.65	2.65
3369	Solid Mechanics	4	a,c,e,k	4.28; 4.23; 4.37; 4.19	4.26
		focused on	a,c,e,k	4.28; 4.23; 4.37; 4.19	4.26
3445	Materials Science	7	a,b,c,d,e,g,k	3.78; 4.11; 3.56; 3.56, 3.61; 3.50; 3.56	3.66
		focused on	a, b, k	3.78; 4.11; 3.56	3.82
4332	FEA	7	a,c,e,g,h,I,k	4.16; 4.00; 4.37; 3.26; 3.84; 3.95; 4.00	3.94
		focused on	a,c,e,I,k	4.16; 4.00; 4.37; 3.95, 4.00	4.10
4364	Heat Transfer	4	a,c,e,k	4.00; 3.92; 4.00; 3.67	3.90
		focused on	a,c,e	4.00; 3.92; 4.00	3.97
4371	Thermo/Fluids Lab	7	a,b,c,d,e,g,k	4.53; 4.47; 4.00; 3.87; 4.40; 4.40; 4.14	4.26
		focused on	a,b,c,e,g,k	4.53;4.47;4.00; 4.40; 4.40; 4.14	4.32
4372	Vib/Controls Lab	7	a,b,c,d,e,g,k	4.35; 4.41; 3.82; 4.50; 4.12; 4.07; 4.18	4.21
		focused on	a,b,c,d,e,k	4.35; 4.41; 3.82; 4.50; 4.12; 4.18	4.23
4334	Capstone Design	8	b,c,d,e,f,g,I,k	3.83; 4.33; 4.00;4.00; 4.00; 4.42; 4.00; 3.83	4.08
		focused on	c,d,e,f,g,i	4.33; 4.00; 4.00;4.00; 4.42; 4.00	4.13
	Averages	all			**3.90**
		focused			**3.99**

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c. an ability to design a system, component, or process to meet desired needs;
d. an ability to function on multi-disciplinary teams;
e. an ability to identify, formulate, and solve engineering problems;
f. an understanding of professional and ethical responsibility;
g. an ability to communicate effectively;
h. the broad education necessary to understand the impact of engineering solutions in a global and societal context;
i. a recognition of the need for, and the ability to engage in, life-long learning;
j. a knowledge of contemporary issues, especially those related to mechanical engineering;
k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Table 7: Focused Outcomes vs. Courses

2334	4.24				4.17							0
2336	4.03				4.00							0
2361			4.29	**4.35**		**4.18**	**4.07**	**4.18**		**3.86**		5
3334	3.63		3.11		**3.51**						3.24	1
3336	4.06				4.00							0
3338	**4.57**		**4.26**		**4.17**						**4.17**	4
3360	4.41	**4.48**		**4.26**			**4.30**		**4.33**		**4.30**	5
3363					2.65							0
3369	**4.28**		4.23		4.37						3.19	1
3445	**3.78**	**4.11**									3.56	2
4332	**4.16**		4.00		3.37				**3.95**		**4.00**	3
4364	**4.00**		**3.92**		4.00							2
4371	4.35	**4.47**	**4.00**		**4.40**		**4.40**				**4.14**	5
4372	4.35	**4.41**	**3.82**	**4.50**	**4.12**						**4.18**	5
4334			**4.33**	**4.00**	**4.00**	**4.00**	**4.42**		**4.00**			6
# of Courses addressing a specific Outcome	5	4	5	4	5	2	4	1	3	1	5	

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c. an ability to design a system, component, or process to meet desired needs;
d. an ability to function on multi-disciplinary teams;
e. an ability to identify, formulate, and solve engineering problems;
f. an understanding of professional and ethical responsibility;
g. an ability to communicate effectively;
h. the broad education necessary to understand the impact of engineering solutions in a global and societal context;
i. a recognition of the need for, and the ability to engage in, life-long learning;
j. a knowledge of contemporary issues, especially those related to mechanical engineering;
k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

new "junior" seminar to address some of the "softer" Program Outcomes. With all three of these possibilities, the outcomes vs. course matrix evolves into Table 8. Four outcomes are now assigned to the freshman course (1100); two to the technical communications course; and three to the (still) proposed junior seminar. Finally, in Table 7, we see that two courses have only one outcome each. If these are reassigned (Table 9), we end up with outcome assessment requirements in only 12 of the 18 courses. The capstone design course (4334) ends up with seven outcomes; two courses, with six outcomes; and three courses, with five outcomes a piece. Three of these five are laboratory courses (3360, 4371 and 4371), and the fourth is an early design course (2361). It is now up to the faculty to develop and implement the necessary assessment instruments in the twelve courses.

Table 8: Initial Outcomes vs. Course Matrix

Courses	OUTCOMES* a	b	c	d	e	f	g	h	i	j	k	# of outcomes
1100												4
2334	4.24				4.17							0
2336	4.03				4.00							0
2361			4.29	**4.35**		**4.18**	**4.07**	**4.18**		**3.86**		5
3334	3.63		3.11		**3.51**						3.24	1
3336	4.06				4.00							0
3338	**4.57**		**4.26**		**4.17**						4.17	3
3360	4.41	**4.48**		**4.26**			**4.30**		4.33		**4.30**	5
3363					2.65							0
3369	**4.28**		4.23		4.37						3.19	1
3445	**3.78**	**4.11**									3.56	2
4332	**4.16**		4.00		3.37				3.95		**4.00**	2
4364	**4.00**		**3.92**		4.00							4
4371	4.35	**4.47**	**4.00**		**4.40**		**4.40**				**4.14**	6
4372	4.35	**4.41**	**3.82**	**4.50**	**4.12**						**4.18**	5
4334			**4.33**	**4.00**	**4.00**	**4.00**	**4.42**		**4.00**			7
College Technical Communications Course												2
New Junior Seminar												3
# of courses	5	4	5	5	6	4	5	4	3	4	5	

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c. an ability to design a system, component, or process to meet desired needs;
d. an ability to function on multi-disciplinary teams;
e. an ability to identify, formulate, and solve engineering problems;
f. an understanding of professional and ethical responsibility;
g. an ability to communicate effectively;
h. the broad education necessary to understand the impact of engineering solutions in a global and societal context;
i. a recognition of the need for, and the ability to engage in, life-long learning;
j. a knowledge of contemporary issues, especially those related to mechanical engineering;

Discussion

ABET has presented engineering programs with a significant, but fair, challenge: Develop a meaningful program based on the needs and desires of your constituents and then show us that your program does what you say it does. Assessment of learning in specific categories (Outcomes) is particularly challenging, and some might say it could detract from the "teaching" in already overloaded curricula. However, most faculty have been complaining for some time about the decreasing academic qualifications of the students graduating from our undergraduate engineering programs. Perhaps ABET's message is that we have some responsibility for improving this situation. This paper has presented a methodology for gathering student opinions which can serve as one indirect measure of their learning and as one of several inputs to a comprehensive assessment process.

Table 9: Final Outcome vs. Course Matrix

	OUTCOMES*											# of
Course	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**Outcomes**
1100												4
2334	4.24				4.17							0
2336	4.03				4.00							0
2361			4.29	4.35		4.18	4.07	4.18		3.86		5
3334	3.63		3.11		3.51						3.24	0
3336	4.06				4.00							0
3338	4.57		4.26		4.17						4.17	3
3360	4.41	4.48		4.26			4.30		4.33		4.30	5
3363					2.65							0
3369	4.28		4.23		4.37						3.19	0
3445	3.78	4.11									3.56	2
4332	4.16		4.00		3.37				3.95		4.00	3
4364	4.00		3.92		4.00							5
4371	4.35	4.47	4.00		4.40		4.40				4.14	5
4372	4.35	4.41	3.82	4.50	4.12						4.18	5
4334			4.33	4.00	4.00	4.00	4.42		4.00			7
College Technical Communications Course												2
New Junior Seminar												3
# of Courses	5	4	5	4	6	4	5	4	3	4	5	

*The Department's Undergraduate Program Outcomes expect all graduates receiving the BSME degree to have:
- a. an ability to apply knowledge of mathematics, science, and engineering;
- b. an ability to design and conduct experiments, as well as to analyze and interpret data;
- c. an ability to design a system, component, or process to meet desired needs;
- d. an ability to function on multi-disciplinary teams;
- e. an ability to identify, formulate, and solve engineering problems;
- f. an understanding of professional and ethical responsibility;
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- j. a knowledge of contemporary issues, especially those related to mechanical engineering;
- k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Conclusions

A procedure has been described for assessing course content using student surveys. Students have been asked to provide their opinions on the issues:

- Was I properly prepared for this course? (Prerequisites)

- Did I satisfy the specific objectives of this course by acquiring specific information or learning certain methodologies? (Course Learning Objectives)
- Did I improve my ability or knowledge in a few specific areas which taken together with a few other areas represent my discipline? (Program Outcomes)

Example survey instruments and example compiled survey results were displayed. A simple procedure was described for improving course content based on these survey results. It was also proposed that these survey results could be used to develop a program assessment process based at the course level.

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