Introducing a Tool for Evaluating Course Objectives (TECO) for a new Engineering Program

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Abstract

The Citadel School of Engineering has initiated a Bachelor's of Science in Mechanical Engineering program in the fall 2014. During the first semester various classes have been offered to freshmen, sophomores and juniors. This paper will describe an evaluation tool, TECO – a Tool for Evaluating Course Objectives, used throughout the semester that allows instantaneous assessment, analysis and continuous improvement that can be implemented before the end of semester. This evaluation tool will also produce an archival record of all course assessment activities. As a spreadsheet it is easy to navigate, manage and adjust, and very transparent to evaluators as it shows all graded work and how those activities support the course objectives. As a course planning tool, the matrix will show where there are shortfalls and strengths in the course content and will allow instructors to adjust requirements before the term ends.

Keywords

ABET accreditation, course objectives, new engineering program

ABET Accreditation

ABET is a non-profit and non-governmental accrediting agency for academic programs in the disciplines of applied science, computing, engineering, and engineering technology.[1] ABET is a recognized accreditor in the United States by the Council for Higher Education Accreditation. ABET accreditation provides assurance that a college or university program meets the quality standards established by the profession for which the program prepares its students. To date, ABET has accredited over 3,400 applied science, computing, engineering, and engineering technology programs at nearly 700 colleges and universities in 28 countries worldwide.

The ABET accreditation gives an assurance that the professionals that serve the population have a solid educational foundation and are capable of leading the way in innovation, emerging technologies, and in anticipating the welfare and safety needs of the public. Thus the accreditation impacts students, programs and institutions, businesses, industry, government and the public.

The ABET accreditation is a process where educational programs or institutions are reviewed to determine if they meet certain standards of quality. The accreditation is not a ranking system but an assurance that a program or institution meets established quality standards. The ABET engineering accreditation criteria cover all aspects of program evaluation, from high level institutional program educational objectives down to individual program outcomes, including evaluation of a program's continuous improvement processes.[2]

- Program Educational Objectives are broad statements that describe what graduates are expected to attain within a few years of graduation. Program educational objectives are based on the needs of the program's constituencies.

- Student Outcomes describe what students are expected to know and be able to do by the time of graduation. These relate to the knowledge, skills, and behaviors that students acquire as they progress through the program. Student outcomes should be defined in order for faculty to have a common understanding of the expectations for student learning and to achieve consistency across the curriculum, as measured by performance indicators. Performance indicators represent the knowledge, skills, attitudes or behavior students should be able to demonstrate by the time of graduation that indicate competence related to the outcome.

- Assessment is one or more processes that identify, collect, and prepare data to evaluate the attainment of student outcomes and program educational objectives. Effective assessment uses relevant direct, indirect, quantitative, and qualitative measures as appropriate to the outcome or objective being measured. Appropriate sampling methods may be used as part of an assessment process.

- Understanding the alignment between educational practices and strategies promotes efficient and effective assessment practices. This can be accomplished by mapping educational strategies (which could include co-curricular activities) to learning outcomes.

- Evaluation is one or more processes for interpreting the data and evidence accumulated through assessment processes. Evaluation determines the extent to which student outcomes and program educational objectives are being attained. Evaluation results in decisions and actions regarding program improvement.

The New Mechanical Engineering Program at The Citadel

The Citadel School of Engineering has had a proud record of significant contributions at The Citadel since its inception in 1842.[3] The Civil and Environmental Engineering Department was established in 1912 and became accredited in 1936. The Electrical and Computer Engineering Department was established in 1941 and became accredited in 1976. The Mechanical Engineering Program was added in 2014 with the first mechanical engineering courses (MECH) offered in the fall. The School of Engineering will apply for accreditation of the new Mechanical program as soon as the first mechanical engineering students graduate, which is expected in May 2016.

The new Mechanical Engineering Program of Study offers focused tracks in Power and Energy, Manufacturing, Aeronautical Systems, Materials (Composites), and Mechatronics. It is available to the cadet population as well as to the evening students transferring from partnering community and technical colleges (2+2 programs). The full-time evening Mechanical Engineering program mirrors the current full-time evening 2+2 programs in Civil and Electrical Engineering.

The new program courses have been prepared using the ABET engineering accreditation criteria and the new team of mechanical engineering faculty is working on collection, assessment and evaluation of the courses in order to provide a quality educational experience for students. Currently Introduction to Mechanical Engineering is offered to the freshman and sophomore cadets and Thermo-Fluids, Computer Aided Design, and Engineering Materials are offered to the evening transfer juniors. The authors believe that a transparent, well-understood process of continuous data collection and course assessment and evaluation is crucial for the success of the new program. Also, early improvement and goal-oriented changes will keep the program viable in the long term.

The new mechanical engineering courses are already thoroughly described and approved by the South Carolina Commission on Higher Education. Each one has a list of course objectives which are being used to evaluate the courses. Once a course is taught, it is critical that each faculty member reviews and critiques the assessment instruments and assessment indicators used to evaluate the course. This ensures the validity of not only the course material, but the evaluation material as well[2]. The course evaluation materials will be archived and used in the program evaluation process for the future ABET accreditation.

The Tool for Evaluating Course Objectives (TECO)

The Mechanical Engineering Program faculty members proposed to use a unified tool for evaluating MECH course objective which will be called TECO. The tool has been based on a tool used by the United States Military Academy to assess their Mechanical Engineering Program and Engineering and Technology outcomes.[4] Each course outcome is evaluated by using embedded indicators which consist of selected graded events that are contained within the course. Each embedded indicator is described and the average grade, the standard deviation of the individual grades and the possible number of points possible for the graded event are recorded. The data for each embedded indicator is then entered into the appropriate course outcome column. Once all data is entered into the spreadsheet, it automatically computes the average and standard deviation for each course outcome.

This form of evaluation is being currently used by the ME faculty in one of the new ME courses, a junior level MECH 304 Engineering Materials, and the outcomes of this new effort will be identified in December 2014. All graded work: homework, projects, quizzes and tests with separated questions, is placed in a matrix allowing an immediate course outcomes assessment and possible changes of future assignments in order to add more embedded indicators where needed, review ‘muddy points’ with students and work on ‘weak spots’ of the course. A short syllabus for MECH 304 can be found in Table 1 and the TECO matrices for this course are showed in Figures 1 and 2. The authors’ goal is that TECO will provide a better, unified, consistent, efficient and transparent evaluation and report across all courses in the new program.

The instructor graded all assignments and partial credit was incorporated.

Table 1. MECH 304 Engineering Materials abbreviated syllabus

THE CITADEL **THE MILITARY COLLEGE OF SOUTH CAROLINA** **Department of Engineering Leadership and Program Management** **MECH 304 Engineering Materials with Lab** **Course Syllabus** **Fall 2014**
Course Description: Course explores the relationships between the microscopic structure and macroscopic properties of materials used in engineering applications. The origin of mechanical, electrical, and thermal properties is studied. Important material failure modes such as occur under fatigue, elevated temperature, rapid loading and corrosive environments are explored. Emphasized is an understanding of the fundamental aspects of atomic and microstructural concepts for proper materials selection, effects of processing on material properties, and enhancement of engineering properties. Materials under study include important metals and alloys as well as key nonmetallic materials such as polymers, ceramics, and composites. Laboratory exercises are integrated throughout the course to provide practical experience in making decisions concerning material composition and processing in order to optimize engineering properties. Experiences from the field are detailed to demonstrate applicability of concepts. Lecture: two hours. Laboratory: two hours.
Course Objective: Upon successful completion of this course, you should be able to do the following: 1) Classify engineering materials 2) Understand their structure and properties 3) Evaluate engineering properties 4) Perform design /material selection for a given engineering problem.
Course Outcomes: Students who successfully complete the course requirements should: 1) Describe and contrast the classes of engineering materials in terms of general microstructure, properties, failure mechanisms and application (ceramics, polymers, composites, biomaterials, nanotechnology, and smart materials). 2) Determine how the atomic structure of materials influences physical and mechanical properties. 3) Distinguish between microstructures utilizing isomorphous and binary phase diagrams to compute phases, compositions and amounts of elemental constituents. 4) Apply processing and strengthening mechanisms to optimize physical and mechanical properties. 5) Apply materials science concepts and knowledge to the proper selection of engineering materials utilizing previously learned engineering principles.
Topics covered: 1) Atomic Structure, Properties and Material Selection (metals, ceramics, polymers) 2) Composites 3) Defects 4) Diffusion 5) Strengthening Mechanisms 6) Phase Diagrams 7) Nanomaterials 8) Biomaterials 9) Smart Materials 10) Semiconductors/Superconductors

Embedded Indicators						1) Describe and contrast the classes of engineering materials in terms of general microstructure, properties, failure mechanisms and application			2) Determine how the atomic structure of materials influences physical and mechanical properties.			3) Distinguish between microstructures utilizing isomorphous and binary phase diagrams to compute phases, compositions and amounts of elemental constituents.			4) Apply processing and strengthening mechanisms to optimize physical and mechanical properties.			5) Apply materials science concepts and knowledge to the proper selection of engineering materials utilizing previously learned engineering principles.		
Indicator	Description	Avg Pts Earned	Stnd Dev Pts	Stnd Dev %	Pts Pssible	Avg Pts Earned	Stnd Dev Pts	Pts Pssible	Avg Pts Earned	Stnd Dev Pts	Pts Pssible	Avg Pts Earned	Stnd Dev Pts	Pts Pssible	Avg Pts Earned	Stnd Dev Pts	Pts Pssible	Avg Pts Earned	Stnd Dev Pts	Pts Pssible
HW 1	Material research	10	0	0.00%	10	10	0	10												
HW 2	Atomic structure	10	0	0.00%	10	10	0	10	10	0	10									
HW 3	Crystal structure	10	0	0.00%	10				10	0	10									
HW 4	Crystal structure	10	0	0.00%	10	10	0	10	10	0	10									
HW 5	Solid solutions	10	0	0.00%	10	10	0	10										10	0	10
HW 6	Diffusion	10	0	0.00%	10				10	0	10				10	0	10			
HW 7	Mech. Properties	10	0	0.00%	10				10	0	10							10	0	10
HW 8	Deformation	10	0	0.00%	10	10	0	10	10	0	10				10	0	10	10	0	10
T1 /5,9,11,12	Crystal structure	34.67	2.08	5.20%	40	34.67	2.08	40												
T1 /6,7,8,10	Properties	38	3.46	8.66%	40				38	3.46	40									
HW 9	Cold work	10	0	0.00%	10										10	0	10			
HW 10	Failure	10	0	0.00%	10	10	0	10	10	0	10									
HW 11	Phase diagrams	10	0	0.00%	10							10	0	10						
HW 12	Phase diagrams	10	0	0.00%	10							10	0	10						
HW 13	Phase transform.	9.67	0.58	5.77%	10							9.67	0.58	10	9.67	0.58	10			
T2 /5,6	Strengthening	17.33	1.53	7.64%	20										17.33	1.53	20			
T2 /7,8,9	Phase diagrams	26.33	6.51	16.27%	40							26.33	6.51	40						
T2 /10	Decarborization	17.00	5.20	25.98%	20				17.00	5.20	20				17.00	5.20	20			
HW 14	Metal processing	10	0	0.00%	10										10	0	10			
P 1	Heat treatment	95.67	3.06	3.06%	100										95.67	3.06	100			
HW 15	Ceramics	10	0	0.00%	10	10	0	10	10	0	10									
HW 16	Ceramic process.	10	0	0.00%	10										10	0	10	10	0	10
Q 1	Steel microstruct.	6.5	0.71	7.07%	10							6.5	0.71	10						
HW 17	Polymers	9.67	0.58	5.77%	10	9.67	0.58	10	9.67	0.58	10									
HW 18	Polymer process.	10	0	0.00%	10	10	0	10							10	0	10	10	0	10
HW 19	Composites	10	0	0.00%	10	10	0	10							10	0	10			
Q 2	Steel microstruct.	10	0	0.00%	10							10	0	10						
T3 /5,6,11	Poly and cer struct.	15.67	1.53	7.64%	20	15.67	1.53	20												
T3 /7,8	Poly and cer. prop.	19.00	1.73	8.66%	20				19.00	1.73	20									
T3 /9,12,13	Steel microstruct.	20.00	5.20	17.32%	30							20.00	5.20	30						
T3 /10	Polymers compar.	9.75	0.58	5.77%	10				9.75	0.58	10							9.75	0.58	10
HW 20	Electr. and magn.	9.33	1.15	11.55%	10													9.33	1.15	10
HW 21	Thermo and optic	10	0	0.00%	10													10	0	10
P 2	Advanced matr.	96.67	2.89	2.89%	100													96.67	2.89	100
HW 22																				
Final																				
Totals						140.00	4.19	150.00	173.42	11.55	180.00	92.50	12.99	120.00	209.67	10.36	220.00	175.75	4.62	180.00
Assessment						93.3%			96.3%			77.1%			95.3%			97.6%		
Stnd Dev						2.8%			6.4%			10.8%			4.7%			2.6%		

Figure 1. TECO matrix for MECH 304 a week before the final exam

Embedded Indicators						1) Describe and contrast the classes of engineering materials in terms of general microstructure, properties, failure mechanisms and application			2) Determine how the atomic structure of materials influences physical and mechanical properties.			3) Distinguish between microstructures utilizing isomorphous and binary phase diagrams to compute phases, compositions and amounts of elemental constituents.			4) Apply processing and strengthening mechanisms to optimize physical and mechanical properties.			5) Apply materials science concepts and knowledge to the proper selection of engineering materials utilizing previously learned engineering principles.		
Indicator	Description	Avg Pts Earned	Stnd Dev Pts	Stnd Dev %	Pts Pssible	Avg Pts Earned	Stnd Dev Pts	Pts Pssible	Avg Pts Earned	Stnd Dev Pts	Pts Pssible	Avg Pts Earned	Stnd Dev Pts	Pts Pssible	Avg Pts Earned	Stnd Dev Pts	Pts Pssible	Avg Pts Earned	Stnd Dev Pts	Pts Pssible
HW 1	Material research	10	0	0.00%	10	10	0	10												
HW 2	Atomic structure	10	0	0.00%	10	10	0	10	10	0	10									
HW 3	Crystal structure	10	0	0.00%	10				10	0	10									
HW 4	Crystal structure	10	0	0.00%	10	10	0	10	10	0	10									
HW 5	Solid solutions	10	0	0.00%	10	10	0	10										10	0	10
HW 6	Diffusion	10	0	0.00%	10				10	0	10				10	0	10			
HW 7	Mech. Properties	10	0	0.00%	10				10	0	10							10	0	10
HW 8	Deformation	10	0	0.00%	10	10	0	10	10	0	10				10	0	10	10	0	10
T1 /5,9,11,12	Crystal structure	34.67	2.08	5.20%	40	34.67	2.08	40												
T1 /6,7,8,10	Properties	38	3.46	8.66%	40				38	3.46	40									
HW 9	Cold work	10	0	0.00%	10										10	0	10			
HW 10	Failure	10	0	0.00%	10	10	0	10	10	0	10									
HW 11	Phase diagrams	10	0	0.00%	10							10	0	10						
HW 12	Phase diagrams	10	0	0.00%	10							10	0	10						
HW 13	Phase transform.	9.67	0.58	5.77%	10							9.67	0.58	10	9.67	0.58	10			
T2 /5,6	Strengthening	17.33	1.53	7.64%	20										17.33	1.53	20			
T2 /7,8,9	Phase diagrams	26.33	6.51	16.27%	40							26.33	6.51	40						
T2 /10	Decarborization	17.00	5.20	25.98%	20				17.00	5.20	20				17.00	5.20	20			
HW 14	Metal processing	10	0	0.00%	10										10	0	10			
P 1	Heat treatment	95.67	3.06	3.06%	100										95.67	3.06	100			
HW 15	Ceramics	10	0	0.00%	10	10	0	10	10	0	10									
HW 16	Ceramic process.	10	0	0.00%	10										10	0	10	10	0	10
Q 1	Steel microstruct.	6.5	0.71	7.07%	10							6.5	0.71	10						
HW 17	Polymers	9.67	0.58	5.77%	10	9.67	0.58	10	9.67	0.58	10									
HW 18	Polymer process.	10	0	0.00%	10	10	0	10							10	0	10	10	0	10
HW 19	Composites	10	0	0.00%	10	10	0	10							10	0	10			
Q 2	Steel microstruct.	10	0	0.00%	10							10	0	10						
T3 /5,6,11	Poly and cer struct.	15.67	1.53	7.64%	20	15.67	1.53	20												
T3 /7,8	Poly and cer. prop.	19.00	1.73	8.66%	20				19.00	1.73	20									
T3 /9,12,13	Steel microstruct.	20.00	5.20	17.32%	30							20.00	5.20	30						
T3 /10	Polymers compar.	9.75	0.58	5.77%	10				9.75	0.58	10							9.75	0.58	10
HW 20	Electr. and magn.	9.33	1.15	11.55%	10													9.33	1.15	10
HW 21	Thermo and optic	10	0	0.00%	10													10	0	10
P 2	Advanced matr.	96.67	2.89	2.89%	100													96.67	2.89	100
HW 22	Corrosion	9.67	0.58	5.77%	10													9.67	0.58	10
Final /5,6,8	Mat. properties	20.67	9.29	30.97%	30	20.67	9.29	30												
Fin. /2,4,9,10	Steel microstruct.	34.33	4.62	11.55%	40							34.33	4.62	40						
Final /1,3,7	Mat. Comparison	25.67	5.13	17.11%	30													25.67	5.13	30
Totals						160.67	13.48	180.00	173.42	11.55	180.00	126.83	17.61	160.00	209.67	10.36	220.00	211.08	10.33	220.00
Assessment						89.3%			96.3%			79.3%			95.3%			95.9%		
Stnd Dev						7.5%			6.4%			11.0%			4.7%			4.7%		

Figure 2. TECO matrix for MECH 304 after the final exam

Based on the results collected up to the final exam (Figure 1) it can be seen that the course outcome 3 gave the lowest assessment score (77.1%), see Table 2. Therefore it was reevaluated during the final. Also the number of embedded indicators for this outcome was the lowest, thus it should be tested more in the future. The instructor of the course suggests using more quizzes and possibly a project or other individual assignments. If the assessment score stays low the instructor should focus more on teaching and reviewing the troublesome topics. This year during a review before the final exam the instructor went over course material, previous tests questions and homework problems related to outcome 3. Figure 2 and Table 2 show how the added embedded indicators selected for the final exam changed the assessment results.

Table 2. TECO summary for MECH 304

Course Outcomes	1		2		3		4		5	
Before and after final exam	Before	After	Before	After	Before	After	Before	After	Before	After
Assessment	93.3%	89.3%	96.3%	96.3%	77.1%	79.3%	95.3%	95.3%	97.6%	95.9%
Standard Deviation	2.8%	7.5%	6.4%	6.4%	10.8%	11.0%	4.7%	4.7%	2.6%	4.7%
Number of embedded indicators	12	13	13	13	7	8	11	11	9	11

Conclusions

The TECO tool provides a common basis for evaluation across all program courses, adds ease-of-use and transparency to the evaluation efforts, and produces a concise, useful set of course evaluation data. The course outcomes assessment shown indicates that all outcomes were supported by each of the embedded indicators. The course instructor observed an increase in course visibility, better and more efficient course planning, better course assessments and evaluations, and expects reductions in the time required to perform end-of-course evaluations. The authors hope TECO will provide increased program visibility, more consistent reporting across all courses in the program, and a greatly improved process of on-going data gathering, analysis, and program evaluation. The TECO is also planned to be used for ABET student outcomes evaluations in the future. The transition from course objectives to ABET outcomes should be relatively easy once the tool is fully developed and commonly utilized.

Acknowledgements

The authors would like the acknowledge the Department of Civil and Mechanical Engineering at the United States Military Academy for sharing their Mechanical Engineering Program Assessment Tool, which served us as a template for TECO.

References

1 ABET, retrieved from http://www.abet.org
2 Nordstrom G., Pettit J., "A Syllabus-Based Assessment and Evaluation Tool for ABET Program Accreditation," ASEE Annual Conference, ASEE, 2010, paper 1207
3 The Citadel School of Engineering, retrieved from http://www.citadel.edu/root/engineering
4 Crawford B., "Using Student Performance and Faculty Experience to Assess a Mechanical Engineering Program," ASEE Annual Conference, ASEE, 2007, paper 1372

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