Evaluation of Assessment Tools for Outcome Based Engineering Courses

Drs. Z.T. Deng, Ruben Rojas-Oviedo and Xiaoqing (Cathy) Qian
Mechanical Engineering Department, Alabama A&M University
P.O. Box 1163, Huntsville, AL 35762
Voice: (256) 858-4142, E-Mail: AAMZXD01@AAMU.EDU

Abstract

The implementation of the Accreditation Board for Engineering and Technology (ABET) Engineering Accreditation Criteria 2000 (EAC 2000) into Mechanical Engineering undergraduate curricula is critical to the success of engineering education. The EAC Criteria 2000 emphasizes an outcome based system approach to engineering education. To ensure the quality of the outcome based mechanical engineering program, faculty need to provide assessment tools to measure outcomes of each undergraduate engineering course. The faculty at Alabama A&M University adopted the SEAARK teaching approach for instruction and teaching. SEAARK stands for Knowledge, Repetition, Application, Analysis, Evaluation and Synthesis in reverse order. It was based on Bloom's taxonomy. SEAARK starts from the basics to the complex levels of learning. In the past few years, the development of the SEAARK teaching method, mapping of course objectives to ME program objectives has been completed. Mapping of the course contents to ABET criteria and assessment tools were also developed. Useful application data has been collected. This paper describes the evaluation of assessment tools for undergraduate mechanical engineering courses, at Alabama A&M University. Specific data for Fluid Mechanics class is presented. Development, modification and evaluation of assessment tools for course contents are discussed.

I. Background about Alabama A&M University's Mechanical Engineering Program

Alabama A&M University (AAMU), is a land grant historically black university. It is located in the northeast outreach of Huntsville, Alabama, an important world center of expertise for advanced missile, space transportation and electronic research and development. Among the leading industry and government agencies located in the area are NASA Marshall Space Flight Center, Army Aviation and Missile Command Center (AMCOM), Redstone Arsenal Testing Center, The Boeing Company, Northrup Grumman, Lockheed Martin Aerospace and many others associated with high-tech endeavors. These industries and government agencies require large numbers of highly trained engineers, in the areas of manufacturing and propulsion.

In 1997, the Mechanical Engineering program at AAMU was created as the result of a legal desegregation law suit resolution in the civil case CV 83-M-1676. To respond what is important around north Alabama, the Mechanical Engineering program at AAMU was formulated into two options: Manufacturing and propulsion system. The Mechanical Engineering Program's mission is to provide an environment conducive for students to build their self-confidence, develop engineering and professional competences, and elevate the quality of their scholarly and professional endeavors. The ME program is aimed to develop engineering core competencies in manufacturing and propulsion systems to better serve industry and government organizations and corporations with relevant engineering activities in aerospace, automotive, power generation, industrial manufacturing, and related emerging technologies. In both options, areas such as system performance, reliability, safety, concurrent engineering, team work and communication are given special considerations.

The basic criteria for the engineering program's outcomes and assessment requires that graduates must have demonstrated abilities (ABET Criteria 3, a-k [1]), in math, science, engineering, design, teamwork, ethics, communication, and life-long learning. In addition to ABET accreditation criteria 3(a-k) requirements, the Mechanical Engineering (ME) program at AAMU was designed to meet additional requirements by the American Society of Mechanical Engineers, such as (l) an ability to apply advanced mathematics through multivariable calculus, and differential equations; (m) a familiarity with statics, linear algebra and reliability; (n) an ability to work professionally in both thermal and mechanical systems areas including the design and analysis of such systems; (o) a knowledge of contemporary analytical, computational, and experimental practices; (p) a competence in experimental design, data collection, and data analysis; (q) a competence in the use of computational tools; (r) a knowledge of chemistry; and (s) knowledge of calculus-based physics.

Under the criteria (a-s), Mechanical Engineering Faculty at AAMU are being challenged to revise the course content, depth and perspectives of the engineering curriculum. Each course syllabi was required to map course contents to the aforementioned requirements (a-s). Although certain courses do not provide the training for (a) through (s), but the overall curricula will provide comprehensive covering of these elements.

In the summer of 2000, the Mechanical Engineering program at AAMU was successfully accredited by ABET under the EAC 2000 criteria.

II. Assessment Tools for Outcome-Based Courses

The educational objective of the Mechanical Engineering program at AAMU is to provide students with the necessary preparation in mechanical engineering to compete effectively for professional careers in this field and with the motivation for personal and professional growth through lifelong learning.

The educational outcomes of the ME program are:

[1]. The student will demonstrate the necessary competencies in the fundamental education in areas of mechanical engineering, such as thermal and mechanical sciences and system design.

[2]. The student will demonstrate competencies in experimental testing, error analysis, laboratory safety, data acquisition, instrumentation and laboratory report writing.

[3]. The student will demonstrate computer competency and an intelligent use of computers as a tool for developing solutions to engineering problems.

Based on the criteria (a-s), the outcome of each engineering course has to be measurable. The objective of each course has to be designed to meet the overall program objective and outcomes.

In the following sections, ME 360 Fluid Mechanics class will be discussed as an example. ME 360 Fluid Mechanics class is designed to provide the student a basic working knowledge of engineering fluid mechanics with the inclusion of open ended problems in the design of fluid systems and consideration to the economics of fluid systems performance. The student will be able to identify the parameters that characterize the operation of fluid flow in incompressible and compressible flow problems and its application on turbo-machinery systems. Computer program in FORTRAN or in C, MATLAB, and Lab View will be developed and used to support design and Lab projects and analysis. The faculty of the mechanical engineering department at Alabama AAMU adopted SEAARK [2,3,4,5] system approach for instruction and teaching. It starts from the basic to the complex levels of learning. SEAARK stands for (in reverse order) Knowledge, Repetition, Application, Analysis, Evaluation and Synthesis. At the "Knowledge" level, students need to define, introduce, describe, name, relate, explain, identify, and remember concepts and principles. At the "Repetition" level, students need to repeat and discuss concepts and principles. At the "Application" level, students need to apply, demonstrate, interpret, and illustrate concepts and principles learned. At the "Analysis" level, students need to learn to calculate, solve, compute, compare and to derive. At the "Evaluation" level, students need to learn to evaluate, decide, recommend, justify and to assess. At the "Synthesis" level, students need to learn to design, conduct, perform, create, produce and propose new tasks. As shown in Table 1, course contents in Spring 2002 were re-defined according to SEAARK teaching method.

Table 1. Fluid Mechanics Course Contents and Teaching Methods.

#	Course Topic and Contents (SEAARK Keyword)	Teaching Methods	Level of Complexity
1	Introduction to fluid mechanics: **DEFINE, REPEAT, REMEMBER, DESCRIBE, EXPLAIN, AND DISCUSS** the concepts of Incompressible, compressible, subsonic, transonic, supersonic and hypersonic flows. **EXPLAIN** continuum and rarefied fluid.	Lecturing, video presentation and questioning.	Knowledge Repetition
2	**DEFINE, RELATE, EXPLAIN, and DISCUSS** Fluid properties. **REMEMBER** System units. **ILLUSTRATE and DISCUSS** extensive and intensive properties, viscosity and elasticity, surface tension, vapor pressure.	Lecturing, problem solving.	Knowledge Repetition
3	**EXPLAIN, DEFINE, REMEMBER, ILLUSTRATE, INTERPRET, ANALYZE, DERIVE and APPLY** the fundamental principles governing fluid motion. **DEFINE and COMPARE** control volume and control mass approaches. **DERIVE and APPLY** conservation of mass (Continuity equation), viscous stress, pressure measurements, momentum equations, and energy equation to **SOLVE** one-dimensional application problems. **APPLY and DISCUSS** Bernoulli's equation to incompressible and compressible fluid and its application. **DEFINE and REMEMBER** equation of state.	Lecture, supplemental reading, problem solving, study session, multiple laboratory experiments.	Knowledge Repetition Analysis Application
4	**APPLY** the fundamental principles to pipe and channel flows for incompressible fluid: **CALCULAT**E pressure drop in Pipe flow. **ANALYZE** flow pattern, APPLY to channel flow. **DEFINE and CALCULATE** drag and lift. **ANALYZE and COMPARE** laminar flow, turbulent flow. **SOLVE** pressure drop for laminar and turbulent flows.	Lecturing, supplemental reading, virtual laboratory experiment (LABView), computer simulation, simulation tutoring, projects, problem solving, study session, photograph	Knowledge Repetition Analysis Application Evaluation

		of flow visualization.	
5	**DISCUSS** Compressible fluid flow. **DEFINE** Mach number, static and stagnation properties. **DERIVE** relationships between total and stagnation properties. **IDENTIFY** subsonic, transonic, supersonic, and hypersonic flow. **INTERPRET** its flow characteristics.	Lecturing, problem solving, study session.	Knowledge Repetition Analysis Application
6	**PERFORM** Turbo-machinery applications: Flow through turbo-machinery system one-dimensional **ANALYSIS**.	Lecturing, problem solving, scientific presentation. ME ANNEX Helicopter tour.	Knowledge Repetition Analysis Application Evaluation Synthesis
7	**DESIGN** for experiment. **DISCUSS** Flow measurements: **APPLY** Instrumentation system and data analysis. Error analysis, linear regression.	Lecturing, laboratory experiment, ME ANNEX tour.	Knowledge Repetition Analysis Application Evaluation Synthesis
8	**APPLY** principles to computational fluid mechanics. **ILLUSTRATION** of grid generation. **DESIGN, PROPOSE, PRODUCE, EVALUATE, and JUSTIFY** results for design project. Project Report, Oral Presentation.	Lecturing, extra special scientific seminar from industry expert on CFD. Numerical simulation lab. Report, Oral presentation.	Knowledge Repetition Analysis Application Evaluation Synthesis

To guarantee the outcome of the course, the teaching of each topic in the course contents was designed to meet aforementioned criteria (a-s) and evaluated by a set of assessment tools. Notice the keywords in Table 1:

"define, repeat, remember, describe, explain, discuss, illustrate, interpret, analysis, derive, apply, compare, solve, calculate, perform, produce, justify, and evaluate."

These keywords determine the time and effort that the instructor has to spend on each topic. It also indicate the level of complexity for the learning process. The student's learning outcome will be evaluated according to the keywords using the assessment tools. These outcome based course assessment and evaluation tools are a combination of the following:

(1) Homework assignments,
(2) Quizzes,
(3) Exams,
(4) Class Attendance,
(5) Design Project and laboratory written reports,
(6) Design Project Oral Presentation,
(7) Computer Simulation using FORTRAN, C, MatLab, Labview,
(8) Prototype development,
(9) Laboratory Testing / Project teamwork.
(10) Course assessment (by students),
(11) Instructor's teaching performance evaluation (by students).

To guarantee the outcome of the course, the teaching of each topic in the course contents was designed to meet the aforementioned criteria (a-s) and evaluated by a set of assessment tools selected from the above (11) tools. Table 2 shows the mapping of the sample fluid mechanics course topics to criteria (a-s) and its corresponding assessment tools.

Table 2. Mapping of the Fluid Mechanics Contents to Criteria (a-s).

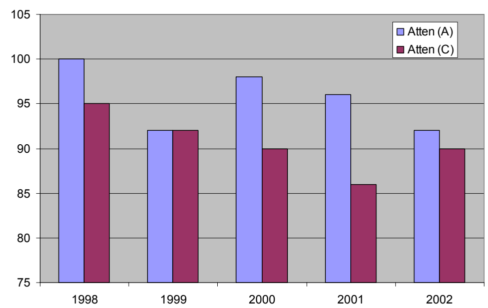
	ME 360 Fluid Mechanics: ABET Criteria 3(a-k) and ME Program Criteria (l-s)																			Course Outcome Assessment Tools
#	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	
1	X				X						X	X								1,2,3,4,10,11
2	X				X						X									1,2,3,4,10,11
3	X		X	X	X	X	X				X	X	X	X	X	X	X		X	1,2,3,4,5,7,9,10,11
4	X	X	X		X						X	X			X					1,3,4,5,7,10,11
5	X	X	X		X						X	X			X			X		1,2,3,4,10,11
6	X	X	X		X		X		X		X	X		X	X					4,5,7,9,10,11
7	X	X	X	X	X						X	X			X	X				3,5,7,9,10,11
8	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	3,4,5,6,7,8,9,10,11

ABET Criteria 3(a-k) and Additional ME Program Criteria (l-s)

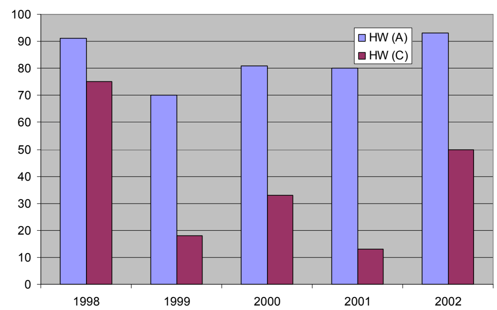
a. an ability to apply knowledge of mathematics, science and engineering;
b. an ability to design and conduct experiments, as well as to analyze and interpret data;
c. an ability to design a system, component, or process to meet desired needs;
d. an ability to function in multidisciplinary teams;
e. 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 an ability to engage in life-long learning;
j. a knowledge of contemporary issues;
k. an ability to use the techniques, skills and modern engineering tools necessary for engineering practice;
l. an ability to apply advanced mathematics through multivariate calculus and differential equations;
m. a familiarity with statistics, linear algebra and reliability;
n. an ability to work professionally in both thermal and mechanical systems areas including the design and analysis of such systems;
o. a knowledge of contemporary analytical, computational, and experimental practices;
p. a competence in experimental design, data collection, and data analysis;
q. a competence in the use of computational tools;
r. knowledge of chemistry;
s. *knowledge of calculus-based physics.*

III. Evaluation of Assessment Tools

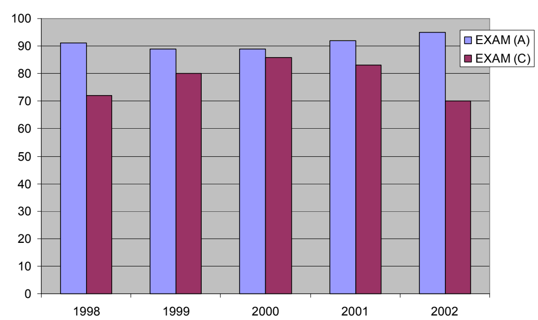
Over the past few years, the Fluid Mechanics course outcome has been assessed using the assessment tools 1 through 9. The achievement of a specific learning and teaching objective is measured by the proposed assessment tools. Teacher's performance was measured against thirty criteria by students in Assessment tools 10 and 11. Feedback from student's performance and teacher's assessment are used to enhance the mapping and assessment tools selection in Table 2. As shown in Figures 1(a) through 1(d), student performance in the last five years was summarized in terms of attendance, homework/quiz, exams and projects. The figures show the average A and C student's performance. Notice that before 2000, course contents and teaching was not defined as Table 1, the teaching was not emphasized in terms of the keywords. In the Fall of 2000, feedback from student course contents review, design projects and exam performance were carefully evaluated. Faculties at ME department revised the SEAARK teaching methodology, and improvement was made to modify the course syllabi to clearly measure student learning outcome. Instructor has to focus on the keywords requirement of the course contents. This new method was implemented in the Fall 2001. This teaching method ensures the teaching quality. It also provides guideline for instructor to evaluate student expected learning outcome. As indicated in Figure 1(a), in the fall of 2001, class attendance for the C-averaged student was poor, as a result, their homework performance were poor simply because homework reflects and re-iterate contents of the classroom teaching. Realized that, instructor has scheduled extra study session. It was shown in Figure 1(c) that the C averaged students exam performance was not dropping significantly. In the year 2002, class attendance was reinforced (Figure 1(a)), homework performance was improved (Figure 1(b)), and student project performance was improved over 2001 (Figure 1(d)).



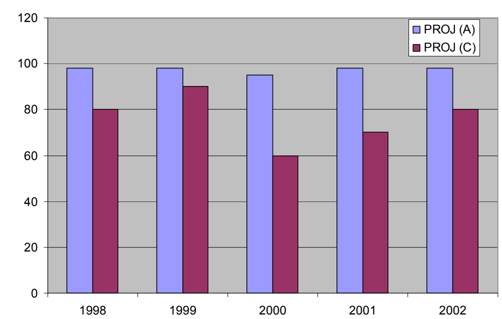
(a) Attendance



(b) Homework and Quiz



(c) Exams



(d) Project

Figure 1. Student Learning Outcome for Averaged A and C students in the past five years.

Over the past five years, student design project performance has been evaluated based on written reports and oral presentations. The key elements that the student had to demonstrate in their design project include

- Were the objectives and purpose clearly stated?
- Was the problem well defined?
- Was the project properly justified (Why?) (Scientific, economic, political, value?)
- Was the design, analysis and modeling understood?

- The approach taken was reached as part of a selection process?
- Are the results technically and economically feasible?
- Effective conclusions / recommendations?
- Quality of the work or design.
- The content was well organized?
- Appropriate use of graphs, charts, board, audio-video.
- Was the message clearly delivered?
- Teamwork was evident in the presentation?

Student's oral presentation will be evaluated by the ME faculty and students participating in the class. Student presentations are videotaped and compared to other ME course oral presentations. Suggestions to improve communication and presentation will be made to students. The assessment also provides student observation on their team member's performance. As indicated in Table 2, the overall student outcome performance can be represented as function of performance of attendance, homework, exams and projects,

$$\text{Student Performance} = \alpha 1 \times \text{Attendance} + \alpha 2 \times \text{Homework} + \alpha 3 \times \text{Exams} + \alpha 4 \times \text{Projects}.$$

Based on the last five year data, to best evaluate student's learning outcome, the best fitted coefficients were obtained as $\alpha 1=5\%$, $\alpha 2=15\%$, $\alpha 3=60\%$, $\alpha 4=20\%$. Figure 2 shows the student overall performance in the past five years. The grade was calculated using the above mentioned weighting factor.

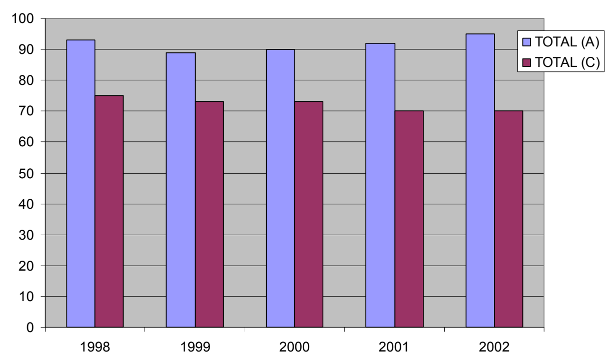


Figure 2. A and C-averaged student performance in ME 360 class for the past five years.

To make the evaluation a continuous improvement process, students will evaluate course contents in terms of learning difficulty and time allocation. Faculty teaching performance were also evaluated based on the following criteria:

"*Appears to know subject; Clearly Explains concepts and ideas; Advise student concern; Advise student concern; Is concerned with student progress; Is concerned with student progress; Uses various assessment devices; Clearly explain the course requirements; Generate enthusiasm in the class; Involving students in question/Answer; Is prepared for class discussion; Meet class at scheduled time; Develop positive working relationship; Is innovative in developing and Presenting materials;"* During the last five years, it was demonstrated that this evaluation criteria works well with the faculty, and it is often used to enhance teaching style and quality.

IV. Conclusions

This paper describes the assessment tools and evaluation of an outcome based engineering undergraduate mechanical engineering course, in particular, Fluid Mechanics, at Alabama A&M University. SEAARK teaching method, mapping of the course contents to criteria (a-s) and assessment tools are discussed. Collected data in the past five years for the Fluid Mechanics class indicated that the student learning performance can be well assessed. The teaching quality and learning outcome can be well measured using these assessment tools. The data give us confidence that the development of assessment tool for the outcome based engineering courses is working in the positive direction.

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ZHENGTHAO DENG

Dr. Z.T. Deng is Associate Professor of the Department of Mechanical Engineering at Alabama A&M University in Huntsville, AL. Dr. Deng has an extensive background and research experience in Computational Fluid Dynamics numerical simulation in particular high-speed aerodynamics/flows with heat transfer phenomena. He earned his Ph.D., Aerospace Engineering, University of Tennessee, 1991, and his Bachelor of Science, Aerospace and Mechanical Engineering, from Beijing University of Aeronautics and Astronautics in 1985.

RUBEN ROJAS-OVIEDO

Dr. Ruben Rojas-Oviedo is Chairperson and Associate Professor of the Department of Mechanical Engineering at Alabama A&M University in Huntsville AL. Dr. Rojas-Oviedo has international engineering experience working both in academe and industry. He has an engineering consulting company and conducts applied research. He earned a Ph. D. In Aerospace Engineering from Auburn University, he has two Masters degrees one in Mechanical Engineering from N.C. State at Raleigh and the other in Applied Mathematics from Auburn. He earned a B.S. degree in Aeronautical Engineering from the National Polytechnic Institute – Escuela Superior de Ingenieria Mecanica y Electrica - in Mexico City, Mexico.

XIAOQING (CATHY) QIAN

Dr. Cathy Qian is Assistant Professor of the Department of Mechanical Engineering at Alabama A&M University in Huntsville, AL. Dr. Qian earned her Ph.D. and M.S. in Mechanical Engineering from the University of Tennessee. Dr. Qian has been working at industry for five years as a Senior System Engineer. She has an extensive experience in instrumentation, measurements, and numerical simulation in particular heat transfer phenomena, and system engineering.