Linking GPA to Engineering Course Outcome

Drs. Z.T. Deng, Xiaoqing (Cathy) Qian and Ruben Rojas-Oviedo
Mechanical Engineering Department, Alabama A&M University
P.O. Box 1163, Huntsville, AL 35762
Voice: (256) 372-4142, 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 measure outcomes of each undergraduate engineering course. Linking the traditional Grade Point Average (GPA) grading system to course outcome is very important. Does GPA reflect student learning outcome correctly? This paper describes the four steps to link GPA to course outcome. Specific data for ME 360-Fluid Mechanics class is presented.

I. Background

The basic criteria for the engineering program's outcomes and assessment requires that graduates must have demonstrated abilities (ABET Criteria 3, a-k), 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 Alabama A&M University (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.

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.

The objective of each course has to be designed to meet the overall program objective and be measurable by criteria (a-s). Questions at hand are: "Does GPA correctly reflect learning outcome?" and "how do we use GPA to measure educational outcome for engineering course?"

In the following sections, ME 360 Fluid Mechanics class will be used as an example to explain the procedure of using GPA to measure engineering course outcome.

II. Using GPA to Measure Course Outcome

In the past seven years, the Mechanical Engineering program at AAMU has developed detailed matrix to map engineering courses to aforementioned criteria (a-s).As discussed in our previous paper [1], SEAARK [2] teaching method, mapping of the course contents to criteria (a-s) and assessment tools were developed. Collected data in the past seven years for the ME 360 Fluid Mechanics class indicated that the student learning performance can be well assessed using the developed assessment tools. The teaching quality and learning outcome can be well measured using these assessment tools. Continuous improvement was made in order to use GPA to measure course outcome. Based on our experience, we summarize the procedure into four steps. They are explained in the following sections, ME 360 Fluid Mechanics class will be used as an example for the discussion.

Step #1: Define Course Contents and teaching methods. 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. ME 360 course contents, teaching methods and level of complexity are defined in Table 1.

Table 1. Fluid Mechanics Course Contents and Teaching Methods.

#	Course Topic and Contents	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
	EXPLAIN, DEFINE, REMEMBER, ILLUSTRATE, INTERPRET, ANALYZE, DERIVE and APPLY the fundamental principles governing fluid motion. **DEFINE and**	Lecture, supplemental	Knowledge

3	**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.	reading, problem solving, study session, multiple laboratory experiments.	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 of flow visualization.	Knowledge Repetition Analysis Application Evaluation
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

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 indicates the level of complexity for the learning process.

<u>*Step #2: Mapping Course Contents to Outcome Based Criteria (a-s).*</u> 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. Table 2 shows the mapping of course topics to criteria (a-s). Instructor will use the criteria as a guideline to teach each topic.

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

	ABET Criteria 3(a-k) and ME Program Criteria (l-s)																		
#	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s
1	X				X						X	X							
2	X				X						X								
3	X		X	X	X	X	X				X	X	X	X	X	X	X		X
4	X	X	X		X						X	X			X				
5	X	X	X		X						X	X			X			X	
6	X	X	X		X		X		X		X	X		X	X				
7	X	X	X	X	X						X	X			X	X			
8	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

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.

Step #3: Evaluate Student Learning of Course contents. 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]:

(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).

Table 3 lists the evaluation tools for each topic and weighting factors used to measure outcome.

Table 3. Evaluation of Student Learning

Course Contents	Evaluation Technique	Weighting Factors on Criteria (a-s)
1	Homework #1	Homework 15% Attendance 5% Exams 60% Design Project 20%
2	Homework #2, Exam #1	
3	Homework #3, Lab #2, Quiz #1, Exams 1,2,3	
4	Homework #4, Exams 1,2,3, Lab #2, Design, Oral Presentation, Project Written Report	
5	Homework #5, Exam #3	
6	Homework #6, Lab #3 Exam #3	
7	Homework #7, Lab #4, 5	
8	Homework #8, Computer Project	

Step #4: Obtain plots of Student GPA vs. Learning Outcome Criteria (a-s). Student course GPA will be determined accordingly. For example, to obtain GPA for criteria C,

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

Based on the last seven year data, to best evaluate student's learning outcome, the best fitted coefficients were obtained as $\alpha 1=5\%$, $\alpha 2=15\%$, $\alpha 3=60\%$, $\alpha 4=20\%$. This was discussed in our previous paper [1]. Figure 1 shows the data in the Fall of 2004 for a B-averaged student performance on each criteria.

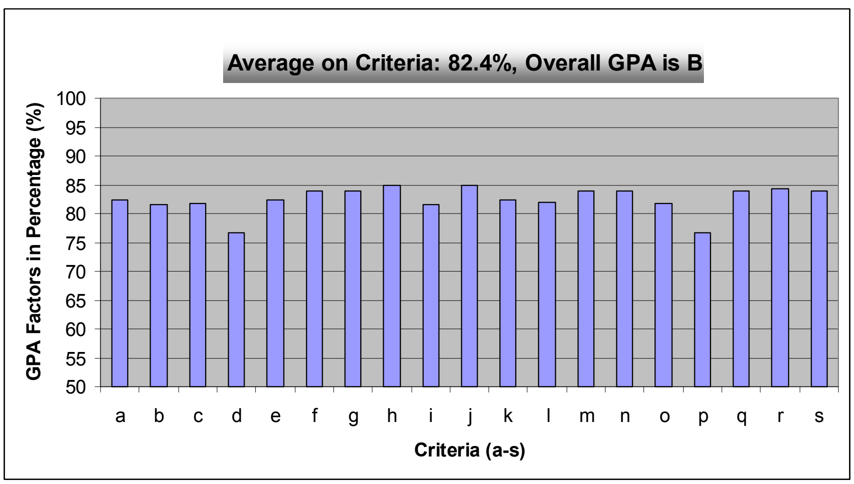

Figure 1. GPA factors for each criteria (B-averaged student performance on ME 360).

It is clearly demonstrated that the overall GPA of the student was correctly interpreted by average of GPA factors on each outcome criteria.

III. Conclusions

This paper describes how to use conventional GPA to measure an outcome based engineering undergraduate mechanical engineering course. Data from ME 360 Fluid Mechanics class was presented as an example. The overall GPA of the student was correctly interpreted by average of GPA factors on each outcome criteria. This paper provides a new way to link GPA to learning outcome.

Bibliography/References:

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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.

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.

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.