AC 2007-1114: IMPROVING TEACHING TECHNIQUE FOR OUTCOME BASED FLUID MECHANICS COURSE AT AAMU

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Improving Teaching Technique for Outcome Based Fluid Mechanics Course at AAMU

Abstract

The Accreditation Board for Engineering and Technology (ABET) Engineering requires that graduates must have demonstrated abilities listed in ABET Criteria 3(a-k). To ensure the attainment and quality of these outcome based mechanical engineering program criteria, faculty needs to develop an inclusive direct assessment process at course level to evaluate student learning related to the overall program outcomes. This paper describes a procedure in the Mechanical Engineering Department at Alabama A&M University to improve teaching technique for outcome based courses. Assessment methods and results were discussed. Examples in teaching of Fluid Mechanics class are discussed in detail.

Introduction

ABET [1] requires that Mechanical Engineering graduates must demonstrate (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; and (k) an ability to use the techniques, skills and modern engineering tools necessary for engineering practice. 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 American Society of Mechanical Engineer, 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.

Outcome can be assessed at the "program level" [2] using standardized testing such as fundamental of engineering exam, or it can be pursued at the "course level". To ensure the teaching quality of the outcome based mechanical engineering program, systematic assessment of engineering curriculum is needed. More importantly, faculty needs to improve teaching techniques so that the student learning of each course can be measured against program outcomes. In the past eight years, the current authors have developed a technique to improve teaching of outcome based engineering course at the Mechanical Engineering

Department of AAMU. Data from ME 360-Fluid Mechanics class has been collected. This paper discusses the teaching technique and collected assessment results for outcome based fluid mechanics course at AAMU.

Mapping Program Outcome to Basic Level Curriculum

To ensure student learning, all Mechanical Engineering courses outcomes are mapped to program outcomes at the curriculum level. SEAARK [3] teaching technique was adopted for all classes. SEAARK stands for knowledge (level 1); repetition (level 2); application (level 3); analysis (level 4); evaluation (level 5) and synthesis (level 6) in reverse order. Figure 1 shows what we expect in basic courses at the program. In the vertical axis 1.0 represents teaching level 6, the highest level of complexity expected. And in the horizontal axis we represent the 18 criteria from ABET a-k outcomes and Additional Mechanical Engineering outcome (l-s) derived from ASME Industry's Top Twenty "Best Practices" for New BS-Level MEs.

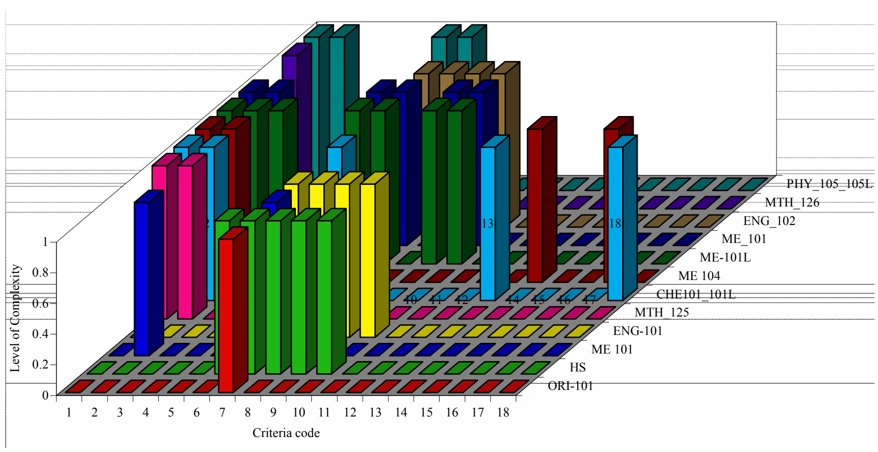


Figure 1. Expected program outcome produced by basic Mechanical Engineering courses [4].

It should be noticed that the expected course outcome indicated in Figure 1 is subject to continuously updated based on student survey and individual course outcome assessment. Not all program outcomes need to be produced in every course. Each instructor at the Mechanical Engineering Department is responsible to provide feedback to the program outcome at the course level. Expected outcomes will be updated annually in order to better assess the program outcome at the curriculum level.

ABET Course Syllabi

At the course level, the first step to effective teaching is to define course contents, teaching methods and assessment 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. Table 1 shows the typical Fluid Mechanics Course syllabi.

Table 1. ME 360 Fluid Mechanics Course Syllabi

Catalog Data: Credit: 3
ME 360 Fluid Mechanics, Lecture 3hrs, Credit 3.
Fundamentals of fluid mechanics are covered. Newtonian fluids, review of system of units, the perfect gas equation, incompressible fluid flow, Bernoulli's equation, channel flow, boundary layers, subsonic flow, flow through converging-diverging passages, compressible flow, potential theory, flow through fluid power system. Relevance to engineering applications. Co-requisite ME 360L. Prerequisite: MTH 227(Offered-consult advisor).

Textbook: Engineering Fluid Mechanics
John A. Roberson and Clayton T. Crowe, John Wiley & Sons, Inc., 8th ed.

References: (1). Lecture notes
(2). An Album of Fluid Motion, Milton Van Dyke. The Parabolic Press, 1982.
(3). Fluid Mechanics, Frank White, 5th Edition, McGraw Hill, 2003.

Coordinator: Zhengtao Deng, Associate Professor of ME

Class Schedule: Monday, Wednesday, Friday, 1:00PM-1:50PM, 50 minutes each session.
Tuesday 2:00-4:50PM Lab.

Prerequisites by Topic:

1. Fundamentals of thermodynamics with applications in open system, one-dimensional isentropic flows.
2. Fundamentals of fluid dynamics and applications to propulsion system.
3. Knowledge of computer programming using FORTRAN, C, MATLAB, or LabView.

Objectives:

This course 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 fluid power systems. At the end of the course the student are expected to learn at a level of analysis and synthesis, i.e. beyond repetition.

#	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
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.	Lecturing, supplemental reading,virtual laboratory experiment (LABView), computer	Knowledge Repetition Analysis

	ANALYZE and COMPARE laminar flow, turbulent flow. **SOLVE** pressure drop for laminar and turbulent flows.	simulation, simulation tutoring, projects, problem solving, study session, photograph of flow visualization.	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 dynamics. **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

Computer Usage:

Computer program in FORTRAN or in C, MATLAB, LabView will be developed and used to support design and Lab projects and analysis.

Instructional Methods:

1. The instructor will present the materials through the use of visual aids, lectures, illustrations, and demonstrations, but the overall responsibility for learning falls upon each student.
2. The instructor will offer free study session during his office hours. This study session is not mandatory for student to come. It will solve problems and review class teaching materials. No new class teaching materials will be presented in this special session.

Evaluation and Grading policy:

1. Homework 15%. *Homework counts for 15% of the final grade. Homework is due by the second class meeting after it is assigned in class. All problems must be labeled, have the student's name at the right hand upper corner, beginning each problem statement at the top of a new page. The instructor may choose to select part or the complete set of problems assigned for each session. Therefore each problem needs to be clearly identified. All calculations must be done clearly stating the units of each variable, showing all the steps needed to arrive to the results. In this subject the procedure and the final result are both important. However, listing the "correct" answer without the correct supporting calculations will receive no credit. The final answer must be "boxed" and at the lower right corner of the paper. Homework will be accepted late the following day only once. Further late homework will not be accepted. In particular homework turned in after the official last day of classes will not be considered for grading. Homework is the student individual scholastic work, cheating and or plagiarism is an unethical conduct that will be subject of severe university disciplinary sanction if such behavior is demonstrated.*
2. Attendance: 5%. *Each student will be responsible for all class sessions. Absences from tests and other academic works may not be made up unless previous arrangements have been made with the instructor. Makeup, if any, will be based on proven valid reasons. Students are required to meet at class schedule and to sign the attendance sheet every class.*
3. Test 60%. *Three test of equal weight for 60% of the final grade. No make-up test will be given except under extreme circumstances and by previous agreement.*

4. Design Project 20%. *Students will participate as team members to develop two projects as determined by the instructor. The project selection will be defined in the early part of semesters. Students are required to submit their project report before the last class of the semester. Student will apply either FORTRAN, C, MATLAB, LabView and TECPLOT to program and visualize data. Student will include a copy of their report in their "design Practice Portfolio".*
5. *Grade Scale: A: 90-100 B: 80-89 C: 70-79 D: 60-69 F: Below 60*

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.

Mapping Course Contents to Outcome Based Criteria

The second step in effective teaching is to map course contents to outcome based criteria. 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. This mapping should be consistent with the curriculum level. It is very important that assessment data need to be collected and analyzed to provide feedback to the curriculum.

Table 2. Mapping of the Fluid Mechanics Contents to Criteria 3(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														
2	X				X														
3	X				X							X							
4	X		X		X	X	X				X	X							
5	X				X														
6	X				X														
7	X	X			X											X			
8	X				X						X	X					X		

Evaluation of Student Learning

The third step of effective teaching is to correctly measure and monitor student's performance. The student's learning is evaluated using the combination of the following:

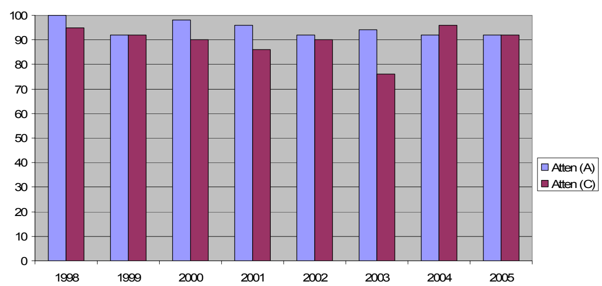
(1). Homework assignments, Computer Simulation using FORTRAN, C, MatLab, Labview, Quizzes;
(2) 3 Exams (Closed book and/or open book);
(3) Class Attendance and participation;
(4) Design Project reports, Project Oral Presentation, and laboratory written reports.

The criteria used to get numerical measurement of student performance is

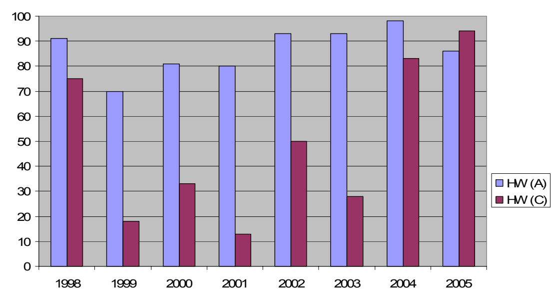
(Student Performance)= α1×(Attendance) + α2× (Homework) + α3× (3 Exams) + α4× (Projects).

Where, α1, α2, α3, and α4 are weighting factors assigned to each evaluation criteria for final grades. Based on data from the last eight years, we concluded that the best distribution of weighting factors are α1=5%, α2=15%, α3=60%, and α4=20%.

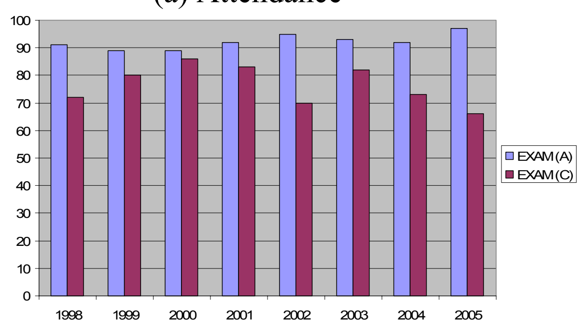
Figure 2 (a)-(e) shows the averaged GPA of (A) and (C) student performance in attendance, homework and quiz, exams, projects and overall performance. In all these figures, the blue bar represents data for averaged A-students in the class, and the pink bar represents data for averaged C students in the class. These data show consistent trend in measuring student learning using the aforementioned criteria.



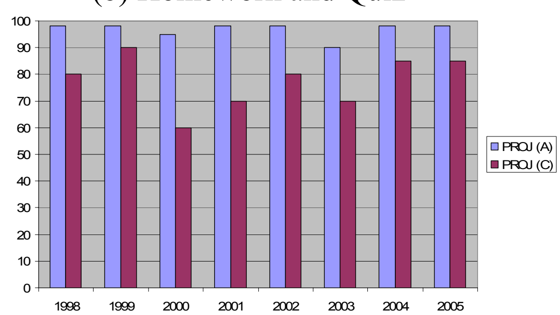
(a) Attendance



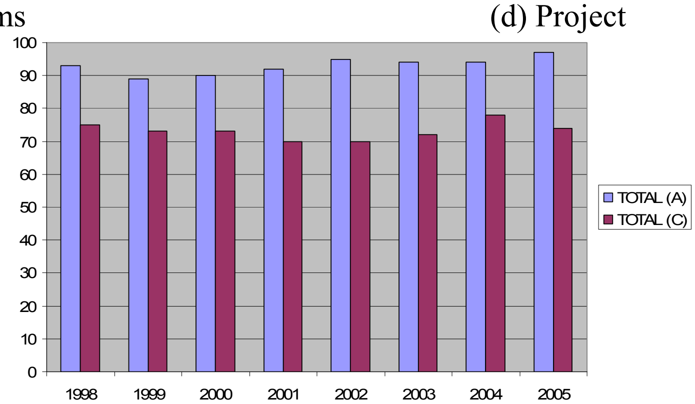
(b) Homework and Quiz



(c) Exams



(d) Project



(e) Overall

Figure 2. Student performance data in 1998-2005.

Assessment

<u>*Course Content Survey:*</u> The first assessment tool used to assess course teaching technique is student survey on the time allocation for topics listed in the course syllabi. The students are asked if more or less time should be allocated for a topic which the class may be already familiar and may be little value-added activity of redundant to review the topic again. Table 3 shows the course evaluation form.

Table 3 Course Content Review Survey Form

Course Contents Review and Suggestions

Class: ME 360 Fluid Mechanics, Fall 2004

Instructions*: Dear students, please take some time to tell us your opinion about the time and effort spent in the following topics. If you feel that in this class more time need to be spend on a topic, write a "+5" on it. If you feel that in this class less time should be spend on a topic, write a "-5" on it. Write "0" if you feel that in this class the amount of time spent on a topic is adequate. Thanks.*

Topics Covered	**Time Allocation Scale:** **(-5…………..0……………..+5)** **Less Time Adequate MoreTime**
1. Introduction to fluid mechanics: Incompressible, compressible, subsonic, transonic, supersonic and hypersonic flows. Introduction of continuum and rarefied fluid.	
2. Fluid properties: System units, extensive and intensive properties, viscosity and elastivity, surface tension, vapor pressure.	
3. Fundamental principles governing fluid motion: Control volume and control mass approach. Conservation of mass (Continuity equation)Viscous stress, pressure measurements. Momentum equations and its application. Energy equation, incompressible and compressible. Combined One-dimensional applications.	
4. Application to Pipe flow, flow pattern, channel flow. Friction coefficient, head loss. Laminar and Turbulent Flow applications.	
5. Compressible fluid flow: Mach number relationships, total and stagnation properties.	
6. Turbo-machinery applications: Flow through turbo-machinery system one-dimensional analysis.	
7. Design for experiment.	
8. Introduction to computational fluid mechanics. Design Project, oral presentation.	
Additional Comments:	

Figure 3 shows the student course content survey for Fluid Mechanics class in the Fall of 2004. The horizontal axis is course content number, and the vertical axis is the class averaged time allocation (percentage). It indicated that harder or more complex topics always seem to need more times. Indeed, topics #3, #4, #5 and #8 are critical contents of the fluid mechanics class. About 12% of the students request the instructor to spend more time on those topics. After evaluating this data, faculty made a corresponding change. More time was spent on teaching of those topics and less time was spend on topic #2 in the following year.

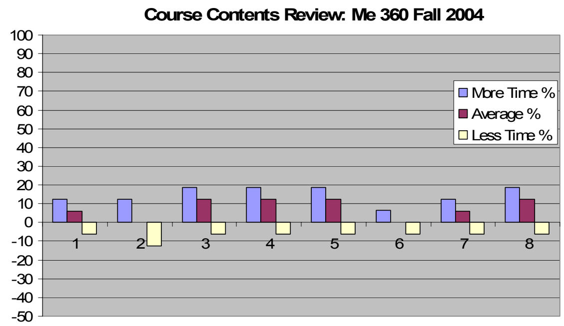


Figure 3. Course contents review by students taking Fluid Mechanics class in Fall 2004.

Direct Assessment: The second assessment tool used to assess teaching techniques was direct assessment of student learning of program outcome through the class. Table 4 lists the evaluation tools for each topic and weighting factors assigned to each evaluation criteria.

Table 4. 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, Project	

Using the criteria proposed in Table 4, Figure 4 shows the calculated student learning outcome of fluid mechanics class from 2003 to 2005. The result is obtained based on class average of student whose course grade is B. In 2004, students have better performance in learning topic #7 and #8, intern, their performance on criteria b; p and q were better. Results also indicated that the current course assessment for criteria b; p and q can not provide accurate information in terms of program outcome for criteria b; p and q. These results show that improvements are needed.

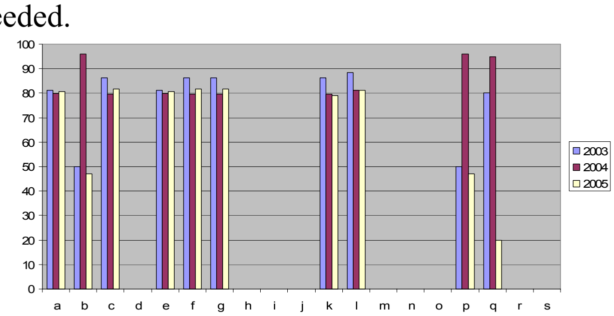


Figure 4. Calculated student learning in percentile (B-Averaged student, ME 360 class) vs. ABET Criteria (a-k) and ME additional criteria (l-s) in 2003-2005.

Student Survey: The third assessment tool used to assess teaching techniques is student survey of program outcomes based on term project. The term project is an open ended design /analysis project. After completion of the project, student is required to evaluate their learning from doing the project. Table 5 shows the student survey form on program outcomes based on their project.

Table 5. Student survey on program outcomes based on project

Assessment Tool Survey 07: Project Self Assessment
Mechanical Engineering Department, AAMU

Class: ______________________ **Instructor:** ____________________

Student Name: ____________________ **Date:** ______________________

Instructions: As a requirement of the project, you need to provide specific documentation that shows where in your report it is documented that you have utilized the following skills.

Skill	**Report Page Numbers**
(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;	

Figure 5 shows the averaged results for 2005 and 2006. More than 80% of students think they utilized skills mentioned in (a-e) and (k). About 60% of students think they utilized skill mentioned in g. This survey results indicated that the expected program outcomes mentioned in Table 2 can be reasonably achieved.

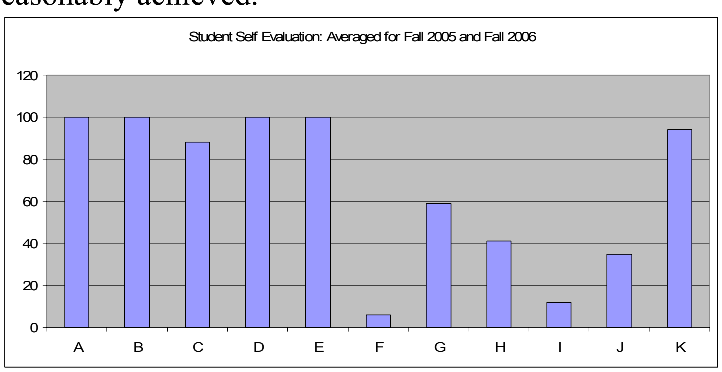


Figure 5. Student survey of program outcomes (Criteria a-k) based on project.

Feedback to Program Outcome

The Department of Mechanical Engineering is engaged in an ongoing assessment process to evaluate its success in meeting the program objectives and to enhance future development and improvement of its program. All faculties were required to continuously evaluate teaching technique to achieve expected program outcomes. Figure 6 shows the student survey of program outcomes based on their project for Mechanical Engineering courses taught by current authors in 2005 and 2006:

ME 300 Mathematical Methods in Mechanical Engineering
ME 312 Heat and Mass Transfer
ME 360 Fluid Mechanics
ME 416 Gas Dynamics
ME 412 Analyses and Synthesis of Gas Turbine Components

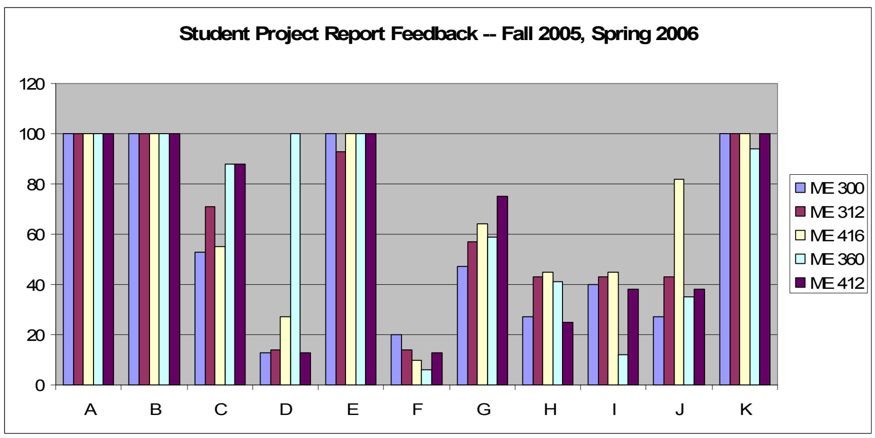


Figure 6. Student survey on program outcomes based on project.

These survey results provide feedback to the mapping of program outcomes to basic level curriculum. It provides useful input to solve the issue that most of the engineering programs were facing: which courses to use for the assessment of each program outcomes.

Conclusion

A procedure developed by the Mechanical Engineering Department at Alabama A&M University to improve teaching technique for outcome based course was discussed. Examples in teaching of Fluid Mechanics class are discussed in detail. Recent successful ABET accreditation suggests that the discussed technique can be applied to teach outcome based engineering courses.

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