DEVELOPMENT OF PERFORMANCE CRITERIA AND MEASURES FOR ASSESSING PROGRAM OUTCOMES IN ENGINEERING TECHNOLOGY PROGRAMS

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Abstract

In the advent of EC 2000, Engineering Technology programs have grappled with methods for assessing the ABET outcomes, especially those skills which are not taught in the traditional technology courses. This paper presents the development of performance criteria and measures for detailed assessment of specific students' performance in the program outcomes in an Engineering Technology (TAC 2007-2008 Criterion 2, a-k outcomes).

Performance criteria have been used to break down each program outcome into concrete measurable actions that students are expected to be able to demonstrate proficiency in the outcome. Defining performance criteria for outcomes is not only the first important step to meaningful assessment of outcomes but also the first step in eliminating ambiguity in the interpretation of outcomes that could vary from faculty to faculty.

For each of the listed outcomes for the ABET Accreditation bodies, detailed performance criteria are presented in this paper. Suggestions on how the performance criteria can be used in a program are described in detail to allow selective adoption of the performance criteria for different courses.

The methodology for defining and using the performance criteria described in this paper enables faculty to (1) fully understand the outcomes, (2) understand a range of performance criteria that need to be measured for each outcome, and (3) remove any ambiguity in the interpretation of the outcomes. In addition, it makes it possible to identify the critical skill-sets to measure for each outcome and makes assessment meaningful for engineering technology programs.

Introduction

In the advent of EC 2000, Engineering, Engineering Technology and Computer Science programs have grappled with methods for assessing the ABET outcomes, especially those skills which are not taught in the traditional courses. Even though several assessment methods have

been published in the literature [1, 2, 3, and 4] for assessing outcomes, there is still a need to establish concrete performance criteria for the outcomes to make the interpretation of assessment results meaningful.

Performance criteria are defined as specific measurable statements that indicate the actions or competencies students should be able to perform or possess at the end of the measurement period. Defining performance criteria for each program outcome is important because it (1) delineates specific statements that identify concrete measurable actions students should be able to perform to meet the outcome, (2) clearly states what needs to be measured, (3) provides common understanding among the faculty on the interpretation of an outcome, thereby removing any ambiguity in the interpretation of an outcome, (4) informs students of the expectations from the outcome, (5) provides focus on the type of data to be collected, (6) provides validity to the assessment results, (7) clearly identifies specific problem areas to be addressed as a result of the assessment process.

To ensure that the performance criteria developed can be used by different programs in the College of Engineering, they were developed based on the program outcomes for Engineering (EAC Criterion 3, a-k outcomes), Engineering Technology (TAC 2007-2008 Criterion 2, a-k outcomes) and Computer Science (CAC Criterion 1, a-i outcomes). The program outcomes from the three ABET Accreditation Commissions were analyzed by the College ABET Assessment Committee. The performance criteria were developed for each similar group of outcomes. In this paper, the outcomes developed for Computer Engineering Technology (CPET) and Electrical Engineering Technology (ELET) programs are presented.

Performance Criteria 'a'

TAC Criterion 2, Outcome 'a' requires, "an appropriate mastery of the knowledge, techniques, skills and modern tools of their disciplines".

Three performance criteria listed below were developed for this outcome group.

1. Students are able to solve problems using current software used in the discipline (such as Matlab, Autocad, Multisim, Pspice, .NET, C++ compiler, etc)
2. Students are able to utilize the latest available hardware/equipment used in the discipline (such as signal generators, oscilloscope, computer hardware)
3. Students are able to utilize latest problem solving and design techniques and methods in their discipline (such as numerical techniques and the design process)

Performance Criteria 'b'

TAC Criterion 2, Outcome 'b' states, "an ability to apply current knowledge and adapt to emerging applications of mathematics, science, engineering and technology". For this outcome group, the performance criteria were based on knowledge and application of mathematics, science, and pre-requisite courses.

The six performance criteria developed for use in measuring this outcome are based on determining whether:

1. Students have the knowledge and the ability to apply basic mathematics involving algebra, geometry, and trigonometry
2. Students have the knowledge and the ability to apply intermediate mathematics involving differential calculus, integral calculus, and probability & statistics
3. Students have knowledge and ability to apply advanced mathematics such as complex and numerical analysis, Fourier series, Laplace transforms, and linear algebra
4. Students demonstrate knowledge and ability to apply chemistry
5. Students demonstrate knowledge and ability to apply physics
6. Students have knowledge and ability to apply named prerequisite courses

By measuring the performance of students in these six areas, it is possible to determine, in finer detail, specific areas that may need improvement. Faculty and students are also made aware of these details and a common ground is created for assessing this outcome.

Performance Criteria 'c'

TAC Criterion 2, Outcome 'c' expects students to have, "an ability to conduct, analyze and interpret experiments and apply experimental results to improve processes". Four performance criteria were developed for this outcome. For each performance criterion, detailed guides for assessing the performance criterion were also provided. The six performance criteria developed for this outcome, are based on determining whether:

1. Students have the ability to conduct experiments
   To assess this performance criteria, it is necessary to determine if students are able to (i) demonstrate general lab safety, (ii) follow experimental procedures for the experiment , while maintaining all safety precautions, (iii) demonstrate knowledge of how equipment functions and their limitations, (iv) complete pre-lab assignment before coming to the lab when required, and (v) collect and record data using appropriate units of measurement and identify the dependent and independent variables in the experiment
2. Students are able to analyze experimental data
   This performance criteria is assessed by students' ability to (i) analyze data to generate the required parameters using appropriate units and significant figures, and (ii) use statistical analysis as needed.
3. Students are able to interpret data
   To measure this outcome, it is necessary to determine students' ability to (i) present the data (raw /derived) in tabular or graphical form to meet the objectives and to aid in interpretation, (ii) discuss the raw and derived data/graphs and assess the validity of the results, (iii) demonstrate the ability to relate how experimental result can be used to improve a process, and (iv) draw appropriate or reasonable conclusions.

Performance Criteria'd'

TAC Criterion 2, Outcome 'd' requires "an ability to apply creativity in the design of systems, components or processes appropriate to program educational objectives. Five performance criteria were developed for this outcome. For each performance criteria, detailed guide for assessing the performance criteria were also provided. The five performance criteria developed for this outcome, are based on

1. Ability to define a problem: This performance criterion is assessed by determining if students are able to (i) identify the customer and the needs, (ii) identify and list the design objectives, and (iii) identify the design constraints.
2. Ability to plan the project: This performance criterion is also assessed by determining if students are able to (i) define the design strategy and methodology, (ii) identify and break down work into tasks and subtasks, and identify the personnel and deliverables for each, (iii) develop a Gantt chart and critical path analysis for managing the project, (iv) establish major milestones for tracking progress and define performance metrics to measure success.
3. Ability to conduct a review of the literature : This performance criterion determines the extent to which students are able to (i) identify the types of information needed for a complete understanding of all aspects of the project (based on tasks described in the project planning), (ii) gather information on relevant fundamentals, theory / concepts, similar existing systems (demonstrate technical competence) and relate them to the design, and (iii) provide the sources in a list of references properly cited in the literature review section and relevant sections of the report.
4. Ability to generate ideas and apply creativity: This is assessed by determining ability of students to (i) define functional requirements for design (specific required actions needed to be performed for the design to be achieved), (ii) transform functional requirements into candid solution concepts / mathematical modeling, and (iii) evaluate solutions to arrive at feasible designs.
5. Ability to perform preliminary and detailed design: Students are able to (i) perform relevant analysis (engineering, mathematical, economic), (ii) develop final design specifications, and identify applicable codes and standards for the design, apply and evaluate realistic constraints (which may include regulations, design, economic, environmental, health, manufacturability and safety constraints considered in design, professional, ethical, social & political issues in design). (iii) select materials, components, software, and test equipment, (iv) fabricate a prototype or a model (physical, software, or hardware) of the design, test or simulate the design and make necessary changes to obtain optimum design.

Performance Criteria 'e'

TAC Criterion 2, Outcome 'e', "an ability to function effectively on teams". Five performance criteria were developed for this outcome. The performance criterion measures the students' ability to:

1. Plan group meetings, time management and team roles (leading, recording, etc)
2. Distribute project tasks evenly to team members
3. Resolve conflicts professionally within the group (Example will be an assignment to identify potential problems and indicate how they will resolve them)
4. Track progress of team members to ensure whether the project is on schedule (Through submission of progress reports)
5. Share ideas, complete assigned task on time, help others, and be professional to each other (through peer evaluation of team members on these characteristics)

Performance Criteria 'f'

TAC Criterion 2, Outcome 'f', "an ability to identify, analyze and solve technical problems.

1. Ability to identify engineering/technical/computing problems: Given a problem, the student is able to (i) understand the given problem and identify the subject area and concept involved, (ii) convert the problem into a well labeled sketch (such as free body diagram, flow chart, functional block diagram, schematic diagram), and (iii) identify the system of units applicable to the problem
2. Ability to formulate/analyze engineering/technical/computing problems: Given a problem, the student is able to (i) define the known and the unknown variables in the problem, (ii) state relevant laws and equations needed for the problem, (iii) list and apply assumptions to the relevant laws and equations to obtain the specific equations appropriate to the problem.
3. Ability to solve engineering/technical/computing problems: Given a problem, the student is able to (i) implement strategy to solve the problem, (ii) solve the problem (showing consistent units throughout), and (iii) evaluate and interpret the results.

Performance Criteria 'g'

TAC Criterion 2, Outcome 'g', "an ability to communicate effectively". Two sets of performance criteria were developed for this outcome group, one set for oral communication and the other set for written communication. The performance criteria for the written communication is based not only on formatting and English details of the report, but also on the structure and technical details required in a senior design project report as required by the Senior Project Report Manual for the College of Engineering at the Prairie View A&M University.

Performance Criteria for Oral Communication

The four performance criteria for oral communication are:

1. Ability to organize and plan communication/presentation: This performance criterion is assessed by determining the extent to which (i) students are able to organize presentation in well structured logical sequence making it easy for audience to follow the content with clear understanding and (ii) students are able to stay within time limits.
2. Ability to demonstrate subject knowledge and provide sufficient technical content This performance criterion is assessed by determining the extent to which (i) students demonstrate knowledge and understanding of the subject. (*This may be demonstrated by presenting literature review, originality, creativity, required standards, constraints, and other appropriate considerations such as economics, environmental, and societal impact*), and (ii) students respond clearly to questions after restating questions to the audience
3. Appearance and ability to provide good oral delivery: This performance criterion is assessed by determining if students are able to: (i) use correct grammatical English and technical terms appropriate to technical area and audience, and speak with clarity and confidence, (ii) maintain good posture and eye contact with the audience (should *not read from note cards or prepared notes*) and elicit the attention of the audience, and (iii) dress appropriately for the occasion.

4. Ability to design/prepare and use appropriate visual aids: This performance criterion measures the extent to which students are able to (i) prepare effective slides (*adequate and relevant technical content, and viewgraphs that are legible, completely labeled/annotated/dimensioned to illustrate important features of the work being presented*), (ii) use modern presentation techniques (*may include visually enhanced transitions, animations, video, and sound clips*), and (iii) prepare and display prototypes or models when necessary. (*Instructor may record the presentation for assessment display purpose, and must ensure to get consent for witness protection from the students).*

Written Communication (Through Senior Project Report Writing)

Following additional six performance criteria for written communication were developed for this outcome based on the requirements in the Senior Design Projects manual[5].

5. Students are able to prepare a well organized and well formatted technical report This performance criterion is assessed by determining how well the written report is formatted. The elements considered include ascertaining whether students (i) provide title page, abstract, and table of contents, list of figures, and list of tables, (ii) provide figure numbers and titles, including discussing and referencing each figure in the text, (iii) provide table numbers and titles, including discussing and referencing each table in the text, (iii) properly cite references in the report and provide well formatted reference list at the end, (iv) provide appropriate and logical sub-headings under each section of the report, and (v) prepare the written report in accordance with standard report formatting provided in the Senior Projects Report Manual.
6. Students are able to use correct English grammar, spelling, and punctuations
7. Students are able describe in details, their understanding of the problem and provide project plans: This performance criterion is assessed by determining if important sections are included in the report and how well these sections are written. The major report sections used to evaluate this performance criterion include: (i) project scope where we look at how well students are able to define and describe the scope of the work being reported (*may include having sections on Problem Statement, Client Identification & Recognition of need, Recognition and Knowledge of Relevant Contemporary Issues, and clearly indicating Goals and Objectives of the work being reported*), (ii) project plans and tasks, where we look at how well students are able to (a) plan and track project by providing task identification, specifying deliverables, timeline, and Gantt chart, and (b) use modern project planning tools (such as Microsoft Project Software) for planning, tracking, and execution of the project, (iii) the literature reviewed where we look at how well students are able to (a) describe relevant topics for literature review, (b) describe previous design or related materials, (c) describe the relevance of materials reviewed to project, and (d) properly cite the references used for literature review.
8. Students are able to present preliminary design: The elements used to assess this outcome include (i) description of design concepts, their evaluation, and rational for selecting best alternative, (ii) description of engineering specifications and preliminary design analysis, and (iii) description of constraints (*which may include sections describing Regulations & Design Constraints considered in design,*

economic, environmental, health, manufacturability & safety constraints considered in design, Professional and Ethical Issues considered in Design as well as Social & Political Issues considered in design).

9. Students are able to present detailed system design/fabrication and technical details in the report: This outcome is assessed by ascertaining how well students able to (i) present in-depth analysis that considers regulations, codes and standards, constraints, objectives, and goals, (ii) describe the use of modern tools in the analysis and design, drawings/schematics/ solid models, simulation and prototype or model development, (iii) clearly describe economic analysis that may include fixed, running cost, amortized cost, unit cost, and other economic considerations, (iv) describe the fabrication/assembly/simulation/testing of the Model or Prototype, and (v) document the physical or computer model, test results, and design verifications.
10. Ability to provide appropriate discussion, conclusions and recommendations
    This performance criterion is assessed by determining how well students are able to clearly (i) summarize the goals, objectives, and indicate whether they were met, (ii) summarize constraints and codes and indicate whether they were met, and (iii) provide logical conclusions and recommendations (including strengths and weaknesses).

Performance Criteria for 'h'

TAC Criterion 2, Outcome 'h', "recognition of the need for, and the ability to engage in life-long learning" Four performance criteria were developed for this outcome group.

1. Students are able to effectively use library and online resources for research and are abreast with current developments in their discipline. (*Instructor can give an assignment requiring students to use other resources to study on their own and use the information studied to solve the problem, or give a library assignment*)
2. Students join and participate in activities of local student chapters of professional or other organizations and are aware of or make use of programs provided by the professional organizations in the areas of training and continuing education.
3. Students are able to identify and take advantage of learning opportunities available on the internet and elsewhere such as seminars, webinars, conferences, workshops and tutorials. *(The instructor should direct the students to identify some of these activities and require them to show documentation of their involvement).*
4. Given an open ended problem, students are able to independently acquire additional knowledge and data needed for solving the problem. *(Instructor may give an assignment that requires students to learn additional information not covered in class for successful completion of the assignment)*

Performance Criteria for 'i'

TAC Criterion 2, Outcome 'i', "an ability to understand professional, ethical and social responsibilities

1. Students understand and demonstrate ethical responsibilities
   This performance criterion is measured by ascertaining if (i) students are able to demonstrate the knowledge of professional code of ethics (*Review code of ethics from one's specific professional society and from the State Board of Professional*

Engineers. Students may be tested on these), (ii) students are able to evaluate case studies and make ethical decisions (*Instructor may present a case study and request students to identify and provide professional and ethical considerations for addressing the problem posed in the case study*), (iii) students acknowledge the work of others they use through proper permission and citation, and (iv) students apply ethics in the academic environment and desists from cheating, plagiarism, and reports such unethical practices to proper authorities.

2. Students understand and demonstrate professional responsibilities
   This performance criterion is assessed by determining if students (i) apply professional standards in (use of handbooks, codes, standards) obtaining, reporting, analyzing data or in design, (ii) attend classes on regular basis and inform professor when excused absence situation occurs (*one can use attendance policy and the professionalism of students in informing and getting excuse for being absent*), and (iii) students demonstrate high academic standards, personal responsibilities (continually looks for own mistakes and opportunities/methods for improvement), and exercises good judgment and discretion (make decisions based upon a defined body of acquired knowledge)
3. Students understand and demonstrate social responsibilities
   This performance criterion is assessed by ascertaining the extent to which (i) students consider and evaluate short and long term impact of a solution on society and environment in arriving at a final solution (*Students may be required to evaluate the impact of their solutions on the local, national, or global society*) and (ii) students are cognizant of the importance of proper engineering knowledge in ensuring the public safety in all engineering designs and decisions they make (the need to use standards, and to design and build as safe as possible).

Performance Criteria 'j'

TAC Criterion 2, Outcome 'j', "respect for diversity and a knowledge of contemporary professional, societal and global issues. The two performance criteria developed for this outcome group are:

1. Students are able to identify current issues (socio-economic, political, environmental, cultural, health and safety) in engineering and technology. *Some examples are global warming, population, depletion of natural resources, alternative energy, outsourcing, security, ecology, engineering/technology workforce development, human rights and environmental pollution.*
2. Students are aware of contemporary issues in industry such as corporate culture, industry-academia-government collaboration, industrial competition, etc. *(Instructor may require the student to identify and discuss several of the contemporary issues recognize consequences take and defend a position and/or write a report.).*

Performance Criteria 'k'

TAC Criterion 2, Outcome 'k', "a commitment to quality, timeliness, and continuous improvement". The three performance criteria used to assess this outcome are listed below:

1. Students prepare and submit assignments of professional quality (uses appropriate media)
2. Students keep and follow time schedules for their studies and other activities, are punctual, and complete homework and other assignments on time.
3. Students strive to and are able to demonstrate academic progress.

Guidelines for using the performance criteria in various programs

Each outcome has anywhere from one to eleven performance criteria that may have to be assessed. Working on the premise that a program does not have to assess every course every semester, or every outcome in a course in a given semester, an opportunity to reduce the amount of work needed for assessing the outcomes exists. However, to ensure that adequate statistical records are maintained for the outcomes and their representative performance criteria, detailed advanced planning by programs are required.

The class average for all performance criteria listed under an outcome are computed and used as the measure for the outcome. The percentage of students with average at or above the departmental expected average are also reported for each outcome and used to ascertain the extent to which the outcome is met by the department or program. For Engineering Technology programs the acceptable class average for an outcome and its performance criteria for the program have been decided at 75%, and an outcome or a performance criterion would be met if at least 70% of the students meet or exceed this average. After reviewing all required courses a matrix was developed for each program. Figure 1 shows performance criteria for the CPET program and Figure 2 shows for the ELET program. The number in the cell for a particular course and outcome indicates performance criteria to be used by the instructor.

Examples for Faculty

Faculty can use following examples to develop assignments to identify the performance criteria in their course. For ELET 3243-Network Analysis course for outcome ‘a’, assignments or tests should be designed to fit ‘1’ and/or ‘3’ which are ‘Students are able to solve problems using Matlab and Multisim software’ and ‘Students are able to utilize numerical techniques for problem solving’. Another example is for the course ELET 1143-AC Circuits. The matrix indicates item 1 for outcome ‘b’ which is to assess ability to apply knowledge of algebra and trigonometry instead of generic application of ‘mathematics, science, engineering and technology’.

Conclusions

The assessment committee in the College of Engineering at the Prairie View A&M University has presented detailed performance criteria that can be used to assess EAC, TAC and CAC recommended program outcomes. Prior to the definition of these performance criteria, different faculty members were assessing the outcomes using their own interpretation of the outcomes, and consequently, it was not exactly clear what those numbers really meant, or what specific areas the students were weak in. This made it difficult to identify true program weaknesses, and appropriate changes to improve the program.

Outcomes Measured in each Course in CPET Program											
Course Number and Title	ABET Outcomes										
	a	b	c	d	e	f	g	h	i	j	k
Courses for CPET Program											
CPET1013 Computer Applications I						1					2
CPET1023 Computer Applications II						3					3
CPET2111 Digital Logic Circuits Laboratory			1				5				
CPET2113 Digital Logic Circuits	2						6				
CPET3161 CPU Architecture Hardware Lab			2				5				
CPET3163 CPU Architecture Hardware	1						6				
CPET3231 Micro. Assembly Language Lab					2	1					
CPET3233 Micro. Assembly Language				2		1					
CPET4061 Data Communications Method Lab			1			2					
CPET4063 Data Communications Method	1	2									
CPET4082 Senior Project I								1	1	1	
CPET4092 Senior Project II								3	2	2	
CPET4111 Software App. Microprocessors Lab					5	2					
CPET4113 Software App. Microprocessors				2		3					
CPET4151 Micro. Controller Peripherals Lab			1				7				
CPET4153 Micro. Controller Peripherals	3	1									
CPET4361 Computer Networks Lab			3			3					
CPET4363 Computer Networks	2	2									
MCET3103 Math Apps for Technology		3				2					

Figure 1 Matrix showing performance criteria for required courses in the CPET program

Outcomes Measured in each Course in ELET Program											
Course Number and Title	ABET Outcomes										
	a	b	c	d	e	f	g	h	i	j	k
Courses for ELET Program											
ELET1111 DC Circuits Laboratory			1				5				
ELET1113 DC Circuits	3										
ELET1141 AC Circuits Laboratory			1				5				
ELET1143 AC Circuits	1, 3	1									
ELET2221 Basic Electronics I Laboratory			1				5				
ELET2223 Basic Electronics I	1, 3	4									
ELET2251 Basic Electronics II Laboratory			1		5						
ELET2253 Basic Electronics II	1, 3	5									
ELET3241 Network Analysis Laboratory						3	5				
ELET3243 Network Analysis	1, 3	2				3					
ELET3451 Robotics I Laboratory				5			5				
ELET3453 Robotics I		2						4			
ELET3521 Instruments and I/O Laboratory			1, 3					1, 4			
ELET3523 Instruments and I/O		5				3					
ELET4082 Senior Project I					5		1, 5		1	1, 2	1, 2
ELET4092 Senior Project II					5		1, 5		1	1, 2	1, 2
ELET4241 Op Amp Theory and Apps. Lab			1, 3		5						
ELET4243 Op Amp Theory and Applications		5		5		3					
TECH1103 Computer Aided Drafting	1			5			5				
TECH3203 Eng/Technical Communication								1	1, 3		

Figure 2 Matrix showing performance criteria for required courses in the ELET program

With the definition of the performance criteria for each outcome, there is now a common understanding of what specifically goes to measure an outcome and all faculty use the same

measures. Thus the assessment numbers are now meaningful. For each outcome, we can now look at the students' progress in each performance criterion, and consequently, can identify the performance area needing improvement in the program.

In conclusion, the methodology for defining and using the performance criteria enables faculty to (1) fully understand the outcomes, (2) understand a range of performance criteria that need to be measured for each outcome. It also removes any ambiguity in the interpretation of the outcomes. In addition, it makes it possible to identify the critical skill-sets to measure for each outcome and makes assessment meaningful to the various programs because it is possible to identify the performance areas needing improvement during closing the loop.

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