3-30-2014

Continuous Improvement in the Assessment Process of Engineering Programs

Youakim Kalaani
Georgia Southern University, yalkalaani@georgiasouthern.edu

Rami J. Haddad
Georgia Southern University, rhaddad@georgiasouthern.edu

Continuous Improvement in the Assessment Process of Engineering Programs

Youakim Kalaani[1] and Rami J. Haddad[2]

Abstract –In this paper, we present a multifaceted assessment process that was developed for our Electrical Engineering (EE) program at Georgia Southern University to meet the ABET criteria dealing with the student learning outcomes (SLOs). Both direct and indirect measures were used to collect and analyze data to assess the attainments of the student learning outcomes. To ensure data integrity, multiple faculty were involved in the development of a set of rubrics with benchmarks and performance indicators at both the program and curriculum levels. These tools provided action plans for this continuous improvement process to be implemented during the academic year. We also describe the mechanism used for assessing student performance at the curriculum level including the use of a course-level outcomes (CLO) form, a continuous improvement efforts (CIE) form, and a student course evaluation (SCE) form. These standardized forms are usually completed by faculty and submitted to the assessment committee for evaluation at the end of the semester. This feedback helped faculty to modify and/or develop new instructional methods to be incorporated into their courses, thus resulting in a more efficient assessment and continuous improvement process.

Keywords: Student Learning Outcomes, Student Course Evaluation, Course Level Outcomes.

INTRODUCTION

Continuous improvement is the process of utilizing the assessment/evaluation results to continuously update and modify the program objectives, revise pedagogy, or even change curriculum. Continuous improvement is by far one of the toughest component to implement and sustain effectively in any Engineering program assessment framework [1]. Engineering programs seeking accreditation are struggling to implement an effective model for continuous improvement while accredited programs have to sustain a functional continuous improvement model to showcase future improvements. To simplify the process, a closely related two-level plan must be developed [2]. The first addressing the continuous improvement at the course-level, while the second addressing the continuous improvement at the program-level. In our Electrical Engineering program, we have developed a three year program assessment and evaluation framework that incorporates the two-level continuous improvement plan. Based on the work by Felder and Brent [4], the ABET student learning outcomes are interconnected and difficult to assess without analyzing the outcomes to their basic elements which were further detailed in the works by Danielson and Rogers [5] and Rodriguez-Marek, et al. [6]. Therefore, we mapped the ABET student learning outcomes into six main skills which were also mapped to our program outcomes. For each skill, a specific rubric with artifacts, benchmarks, and performance indicators are developed to gauge student performance across the curriculum. Based on the assessment results, continuous improvement actions are identified and then used to modify the program objectives, revise pedagogy, change curriculum program. or even revise the assessment process itself.

In this paper, we present an effective assessment process that can be used by engineering programs to meet ABET student learning outcomes. We focus on four main dimensions of this framework, 1) the program assessment

[1] Georgia Southern University, Dept. of Electrical Engineering (EE), P.O. Box 8045, Statesboro, GA 30460, yalkalaani@georgiasouthern.edu

[2] Georgia Southern University, Dept. of Electrical Engineering (EE), P.O. Box 8045, Statesboro, GA 30460, rhaddad@georgiasouthern.edu

process, 2) the student learning outcomes and assessment, 3) the continuous improvement and action plans, and finally 4) the course assessment.

PROGRAM ASSESSMENT PROCESS

To successfully accomplish the program mission, which states in part: "the capability to produce graduates who are well-grounded in the design and practical applications of fundamental principles of science and engineering to meet the needs of program constituencies," it is essential that the EE program has an assessment and evaluation plan that incorporates several levels of continuous improvement. As professionals and employers in the field, the EE Professional Advisory Council (PAC) members offer substantial knowledge and experience in the field. Assessment data are also sought from the programs' other important constituents: employers, alumni, graduating seniors and faculty of the program. There are five major components of the Assessment and Evaluation Process:

Assessment Planning

The highest priority constituents evaluate the current state of the EE program by reviewing the program outcomes and program objectives. PAC members and faculty provide feedback on several focus areas including continuous program improvement, and curriculum enhancement.

- **Data Collection:** various assessment tools are administered and collected from program constituents and student performance reports in selected courses across the curriculum.
- **Data Analysis**: data collected from program constituents and student graded work are processed by the Assessment Committee and strategies for course-level improvements and program improvements are discussed. A summary of suggested program revisions is generated and presented at PAC annual meetings.
- **Program Review**: program assessment and continuous improvement actions reports are submitted to administration for review and inclusion in the University's Institutional Effectiveness Plan (IEP). The Department Chair is responsible for compiling and submitting these reports.
- **Improvement Actions**: feedback from all constituents is reviewed by the Assessment Committee. Modifications to assessment tools, performance criteria, assessment timeline or continuous improvement processes are typically implemented during the next assessment cycle.

The cycle then repeats itself with special attention given to any changes driven by the past assessment cycle. The frequency and cyclic nature of the above described assessment process illustrates closing the loop on the Continuous Improvement plan during the assessment cycle. Multiple assessment tools have been identified as qualifying measures for evaluating the program objectives and student learning outcomes. They are categorized as: 1) indirect measures such as employer or alumni surveys; and 2) direct measures such as student performance on a final exam or project. More detailed descriptions of these assessment tools will be provided in the next few sections.

STUDENT LEARNING OUTCOMES

The followings are the student learning outcomes (SLO's) grouped under six skills categories that EE students are expected to acquire upon graduation as aligned with ABET outcomes (a-k) [3]:

SLO1- Basic Skills
- Apply concepts of mathematics, science, and electrical engineering (a)
- Identify, formulate, and solve electrical engineering problems in a structured and systematic way (e)
- Apply the techniques and modern tools in electrical engineering practice (k)

SLO2- Design Skills
- Design an electrical system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability (c)
- Assess impacts of engineering solutions in global, economic, environmental, and societal context (h)

SLO3- Lab Skills
- Design and conduct electrical engineering experiments, as well as analyze and interpret data (b)
- Function effectively on multi-disciplinary teams to accomplish assigned tasks (d)

SLO4- Inquiry Skills
- Conduct research in electrical engineering discipline as part of life-long learning (i)
- Evaluate engineering systems as pertained to novelty and contemporary issues (j)

SLO5- Profession Skills
- Apply the rules of the code of professional conduct and ethics in electrical engineering (f1)
- Provide alternative outcomes for a given conflict of interest or dilemma (f2)

SLO6- Communication Skills
- Write technical reports that conform to standard engineering terms and formatting (g1)
- Perform professional presentations individually and as part of a team using effective visual techniques (g2)

Assessment of Student Learning Outcomes
Assessment of student learning outcomes is based on direct and indirect measures as follows:

- **PAC/Faculty Survey**
  The PAC/Faculty Survey of the Appropriateness of Program Outcomes is distributed to EE faculty and PAC members typically during their spring meetings every three years to provide feedback on whether the student learning outcomes are appropriate for the attainment of the stated program objectives.

- **Senior Exit Survey**
  The Senior Exit Survey is usually distributed to students in the semester they are graduating. It provides feedback on whether the student learning outcomes are appropriate for the attainment of the stated program objectives.

- **Student Performance**
  Student performance is a direct measure of specific performance indicators using rubrics designed for that purpose. There are at least three performance indicators for each outcome a-k, which are grouped under the five identified skills rubrics as depicted in Table 1.

Table 1 - Student Learning Outcomes Measures

Basic Skills (SLO1)	Performance Indicators
Apply concepts of mathematics, science, and electrical engineering (a)	• Apply math, science, and engineering knowledge • Identify the principles that governs engineering concepts • Express concepts in mathematical forms or equations • Apply analytical, graphical or numerical methods
Identify, formulate, and solve electrical engineering problems in a structured and systematic way (e)	• Identify the governing concepts of the engineering problem • Formulate the problem using mathematical laws • Solve the problem logically with correct steps • Derive correct answers with the appropriate units
Apply the techniques and modern tools in electrical engineering practice (k)	• Identify the right techniques or tools for a given EE application • Apply modern tools to solve engineering problems • Evaluate the benefits and limitations of modern engineering tools
Design Skills (SLO2)	**Performance Indicators**
Design an electrical system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability (c)	• Develop a design strategy, decomposition of work into subtasks and timetable • Develop several potential formulations to the proposed project (system) • Integrate prior knowledge into a new problem showing how areas interrelate • Generate solutions that includes economic and other realistic constraints
Assess impacts of engineering solutions in global, economic, environmental, and societal context (h)	• Analyze variables that affect global, economic, environmental and societal context • Identify variables that affect global, economic, environmental and societal context • Identify operations that affect global, economic, environmental and societal context

Table 1 - Student Learning Outcomes Measures	
Lab Skills (SLO3)	**Performance Indicators**
Design and conduct electrical engineering experiments, as well as analyze and interpret data (b)	• Determine input, output, controllable and uncontrollable variables in model • Determine variable operating ranges influential to system response • Assemble representative circuit/system and signal sources • Apply instrumentation appropriate to measure variables of interest • Report statistically significant and repeatable result
Function effectively on multi-disciplinary teams to accomplished assigned tasks (d)	• Attend all team meetings and contribute a fair share to the project workload • Being alert and prepared for the group meeting with clearly formulated ideas • Assume a designated role in the group including leaderships or a team player • Provide unique expertise and willing to work with others
Inquiry Skills (SLO4)	**Performance Indicators**
Conduct research in electrical engineering discipline as part of life-long learning (i)	• Explore conceptual idea(s) using multiple learning opportunities to solve a problem • Retrieve relevant and/or required information to solve a problem or design a project • Organize information systematically to solve a problem or design a project
Evaluate engineering systems as pertained to novelty and contemporary issues (j)	• Identify emerging technologies impacting the engineering system • Analyze contemporary issues as pertaining to the engineering system • Implement modifications to the engineering system for evolving technologies
Profession Skills (SLO5)	**Performance Indicators**
Apply the rules of the code of professional conduct and ethics in electrical engineering (f1)	• Determine profession's code of ethical conduct (IEEE Code etc.) • Recognize important issues in class discussions and exercises on ethics and professionalism
Provide alternative outcomes for a given conflict of interest or dilemma (f2)	• Distinguish between an acceptable behavior and one that present a conflict of interest • Provide alternative solutions /issues regarding ethical and professional dilemmas
Communication Skills (SLO6)	**Performance Indicators**
Write technical reports that conform to standard engineering terms and formatting (g1)	• State objectives clearly using correct engineering terms • Present supporting evident to advance central idea(s) • Provide comprehensive conclusions • Written in good English with no grammatical errors
Perform professional presentations individually and as part of a team using effective visual techniques (g2)	• Present introduction and conclusions • Present himself/herself professionally • Provide informative supporting materials • Use visual aids effectively

To measure student performance, specific artifacts and rubrics were developed to measures student performance at five achievement levels:

- Exemplary (5) – expected performance level that senior students are inspired to reach
- Proficiency (4) – expected performance level for students in their junior year
- Developing (3) – acceptable achievement for students in their sophomore year
- Beginning (2) – appropriate achievement level for students in their freshmen year
- Introductory (1) – the lowest achievement level on the measuring scale

For demonstration purposes, the rubric to measure Profession Skills (SLO5) is provided in Table 2.

Table 2- Rubric for Measuring Profession Skills (SLO5)

Apply the rules of the code of professional conduct and ethics in electrical engineering (f1)						
	Performance	**Exemplary**	**Proficient**	**Developing**	**Beginning**	**Introductory**
	Indicators	**5**	**4**	**3**	**2**	**1**
	Determine profession's code of ethical conduct (IEEE Code etc.)	Neatly describe in detail the profession's code of ethical conduct, in particular the IEEE Code of Ethics and the GSU Honor Code	Able to name and describe the code(s) of ethical conduct within the discipline in particular the IEEE Code of Ethics and the GSU Honor Code	Able to name most of the practice and procedures of code(s) of ethics and standard(s) of professional practice within the discipline	Able to name few procedures of code(s) of ethics and practice within the discipline	Is unaware or unable to name and identify the profession' code of ethical conduct (IEEE Code of Ethics and the GSU Honor Code)
	Recognize and identify all important issues in class discussions and exercises on ethics and professionalism	Readily able to recognize and identify all important issues in class discussions and exercises on ethics and professionalism	Able to recognize and identify most of the important issues in class discussions and exercises on ethics and professionalism	Able to identify most issues in class discussions and exercises on ethics and professionalism	Partially able to list issues in class discussions and exercises on ethics and professionalism	Unable to identify issues in class discussions and exercises on ethics and professionalism
Provide alternative outcomes for a given conflict of interest or dilemma (f2)						
	Performance	**Exemplary**	**Proficient**	**Developing**	**Beginning**	**Introductory**
	Indicators	**5**	**4**	**3**	**2**	**1**
	Distinguish between an acceptable behavior and between one that present a conflict of interest	Readily able to distinguish between an acceptable behavior and between one that presents a conflict of interest	Able to distinguish between an acceptable behavior and between one that presents a conflict of interest	Able to mostly distinguish between an acceptable behavior and between one that presents a conflict of interest	Able somewhat to distinguish between an acceptable behavior and between one that present a conflict of interest	Not able to distinguish between an acceptable behavior and between one that present a conflict of interest
	Provide alternative solutions /issues regarding ethical and professional dilemmas	Evaluate and judge a situation in practice using personal understanding of the situation and code of ethics and is able to identify and propose alternative course of action/solutions	Evaluate and judge a situation in practice or as a case study using personal understanding of the situation and code of ethics and can identify alternative course s of action/solutions	Can evaluate and judge some situations in practice or as a case study using personal understanding of the situation and code of ethics	Attempt to identify alternative course of action/solutions regarding ethical and professional dilemmas	Unable to identify alternative course of action/solutions regarding ethical and professional dilemmas

Since the EE program is going through its first assessment cycle, the student learning outcomes (a-k) were all measured to pilot test the assessment process and provide a baseline for future reference. However, measuring a-k outcomes will occur less frequently in the future, occurring only at certain levels in the four-year program. The goal of doing so is to capture student performance as a cohort progressing toward graduation.

Data collected are analyzed using standard statistical tools to provide meaningful interpretation of achievements at different levels. Targets are set at 70%, or 3.5 on scale of 5, as follows:

- "Developing" for the Sophomore Level (L1),
- "Proficient" for the Junior Level (L2), and
- "Exemplary" for the Senior Level (L3).

Assessment Results

As stated earlier, the assessment process of student learning outcomes is based on direct and indirect measurements. Table 3 and Figure 1 shows the results of indirect measurements, or surveys, as mean averages on a scale of 5 of the appropriateness of student learning outcomes as perceived by PAC members, EE faculty and EE students. (Note: twenty samples of students' responses were used as feedback). Survey results indicated that all outcomes met the target level (3.5), except that outcome 'i' is slightly below (3.4) target, reflecting the faculty's desire to enhance "students' ability to conduct research in the electrical engineering discipline as part of a life-long learning."

Table 3- Appropriateness of Student Outcomes to Achieve Program Objectives

Surveys Results	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)
PAC (5 members)	5	4.6	4.8	4.8	5	4.6	4.5	4.4	4.6	4.4	4.8
Faculty (9 members)	4.8	4.9	3.8	3.8	4.9	4.45	4.75	3.7	3.4	3.7	4.8
Student Survey (20)	4.4	4.2	4.25	4.35	4.35	4.48	4.13	4.1	4.55	4.15	4.3

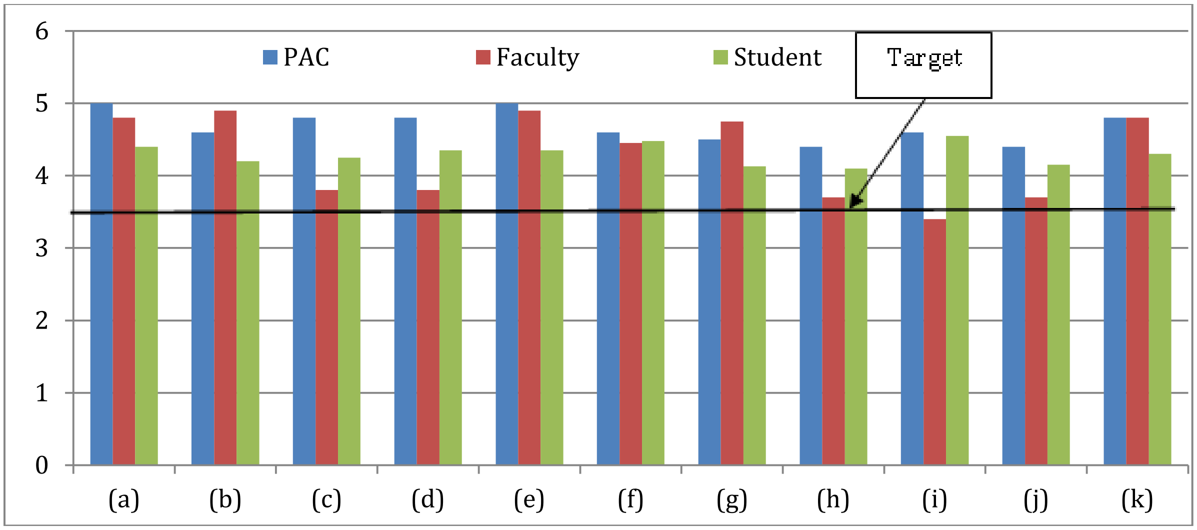


Figure 1- Appropriateness of Student Outcomes to Achieve Program Objectives by the Professional Advisory Committee, Faculty, and Students

As for direct measures, the student learning outcomes were all measured with the results presented in Figure 2 as a baseline for comparison in future assessment years.

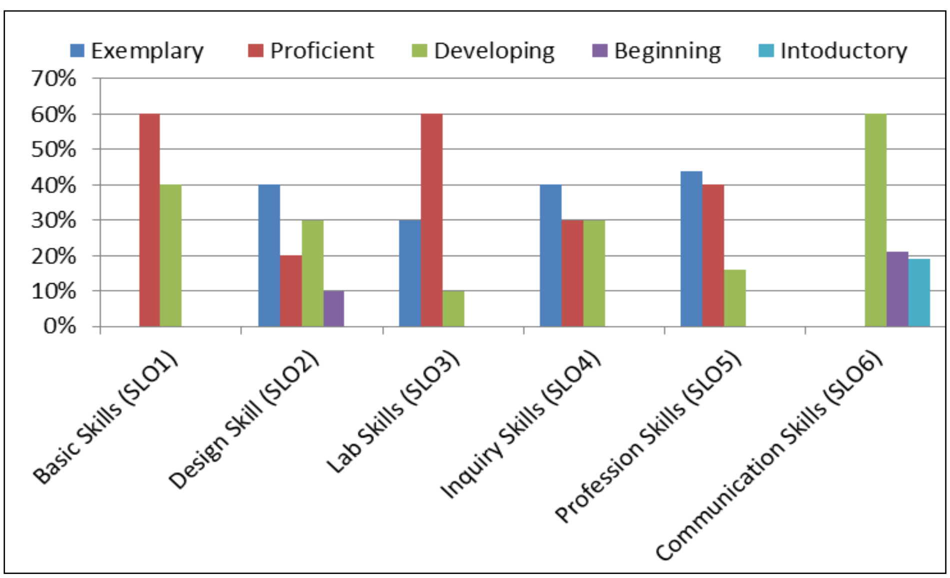


Figure 2- Attainments of Student Learning Outcomes

CONTINUOUS IMPROVEMENT AND ACTION PLANS

To demonstrate the process of continuous improvement, a closer look at the assessment of students learning outcome (SLO4) dealing with profession skills reveals that the performance indicators for that outcome are met to a less or greater degree as shown in Figure 3-a,b. As shown, the two performance indicators for f1 were both met at 70% or higher "Proficient". On the other hand, there were shortcomings (less than 70% Proficient) in one of the performance indicators (f2) for which students were not able to provide alternative outcomes for a given conflict of interests or dilemma and therefore action plans were devised to address this issue.

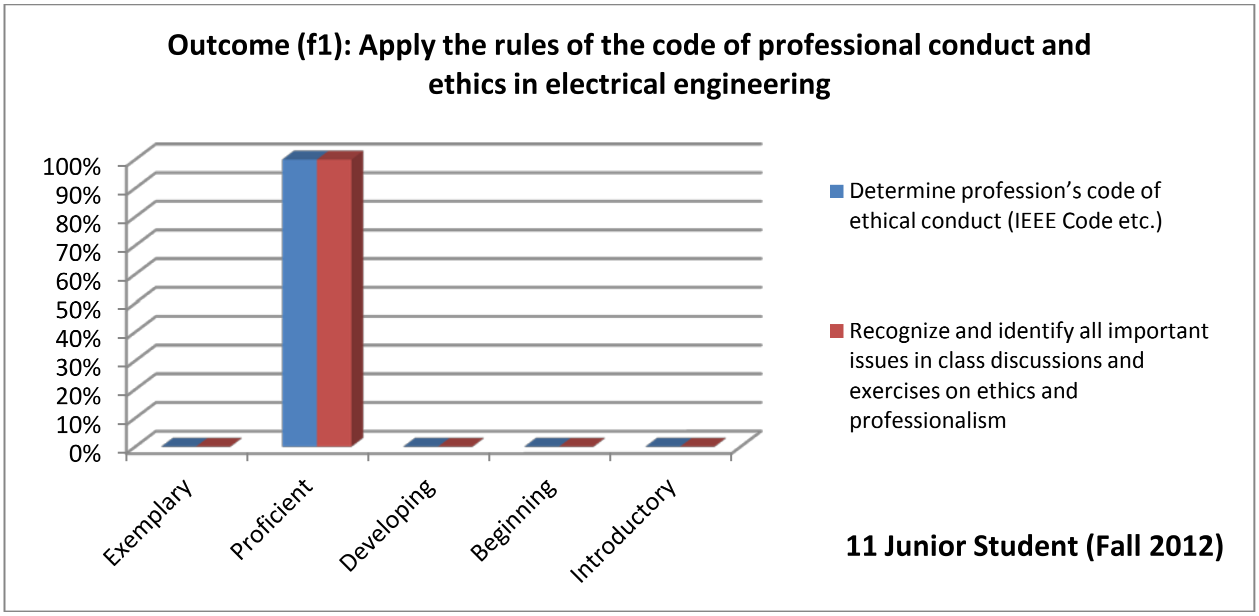


Figure 3a - Assessment Results for the Student Learning Outcome 4 (SLO4) Performance Indicator (f1)

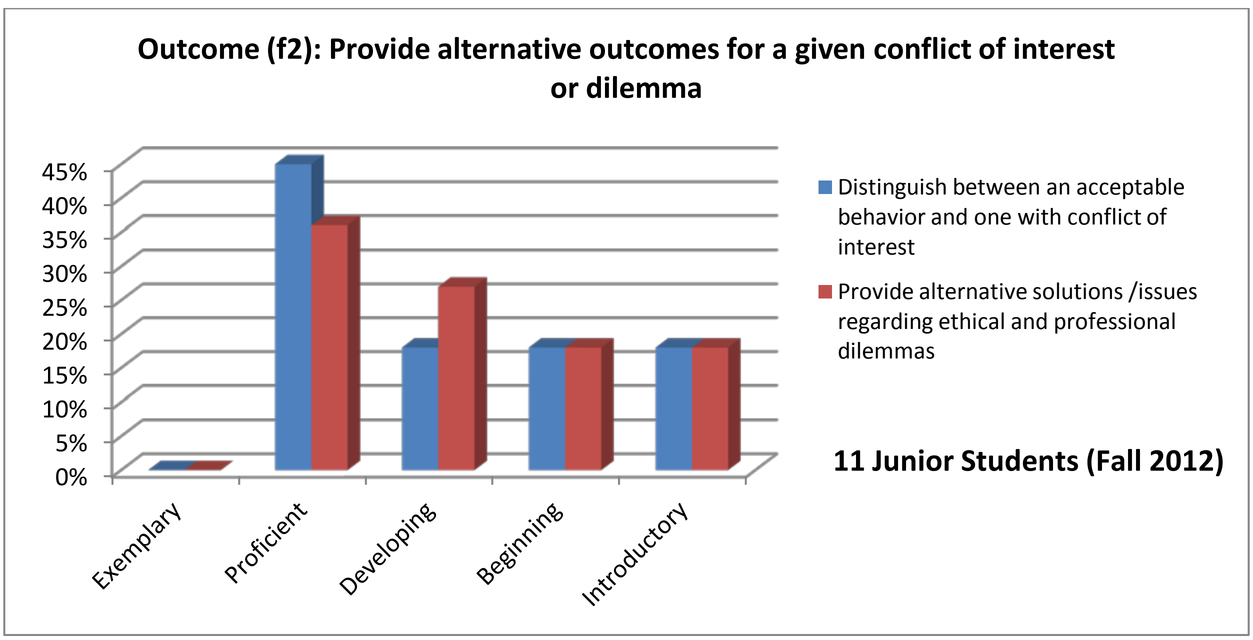


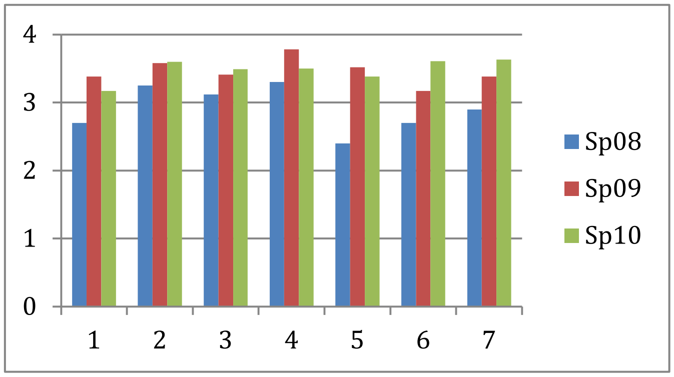
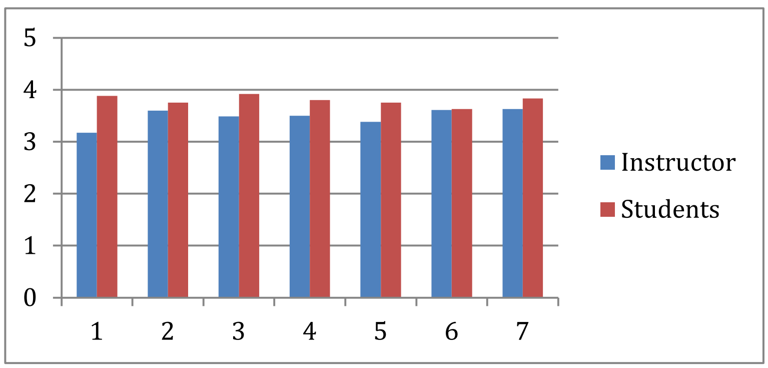
Figure 3b - Assessment Results for the Student Learning Outcome 4 (SLO4) Performance Indicator (f2)

COURSE LEVEL ASSESSMENT

The EE assessment process is also applied at the course level to assess the learning outcomes specified in the course syllabus. Faculty members are required to submit Course Level Outcomes (CLO) forms similar to the one shown in Table 6 where actions are provided to improve instructions at the course level. The instructor also completes and submits a CIE form for each outcome measure that falls below the benchmark as shown in Table 7. The Student Course Evaluation (SCE) with results plotted in Table 7 is an additional tool that faculty can have in their arsenal to assess the attainment of the course educational objectives. It should be noted that many shortcomings that are triggered and reported in the CLO forms, are mostly resolved at the course level, which in turn, contribute to the attainment of the student learning outcomes (SLO's).

Table 6- Course Level Outcome for Electric Machines Course

Course Objectives	Course Outcomes/ Skills Gained Students will be able to:	Outcomes (a-k)	Assessment Instrument/ Evaluation Measure		Average (Actual Level 2/4)	Observation/ Recommendations /Action Plans
1) Describe various types of DC machines and analyze their operation characteristics	1- analyze separately excited , self-excited, shunt , and compound generators 2- control the voltage level across a generator 3- calculate mechanical power and torque 4- analyze the operation of shunt, series, and compound motors. 5- apply plugging and dynamic braking 6- determine losses and effect on efficiency	a,e, b,d	HW	3.35	3.17	Students are not performing well on Exams
			Labs	3.73		
			Exam1	2.89		
			Final	2.70		
2) Describe various types of single-phase motors and analyze their operating characteristics	1- explain the concept of rotating field 2- calculate the value of starting torque 3- analyze the operation of split-phase motors 4- explain the operation of shaded-pole motors 5- explain the operation of stepper motors	a,e, b,d	HW	3.35	3.60	No action required
			Labs	3.73		
			Exam2	3.71		
3) Describe the various types of Transformers and analyze their operating characteristics	1- determine turn ratio and voltage induction 2-derive the equivalent circuit of a transformer 3- determine voltage, current , and power ratings 4- determine impedance matching and reflection 5- connect transf. in delta-wye configurations 6- determine phase-shift and voltage regulation	a,e, b,d	HW	3.35	3.49	No action required
			Labs	3.73		
			Exam2	3.71		
			Final	3.19		
4) Describe various types of 3-phase induction motors and analyze their operating characteristics	1- determine slips and synchronous speeds 2-determine voltage/ frequency induced in rotor 3- estimate currents in induction motors 4- use active power flow method to calculate the mechanical torque and motor efficiency 5- analyze torque-speed curve characteristics 6- explain the operation of squirrel cage and wound-rotor type induction motors 7- derive equivalent circuit of a induction motor	a,e, b,d	HW	3.35	3.50	The equivalent circuit of an induction motor was introduced this time
			Labs	3.73		
			Exam3	3.54		
			Final	3.40		
5) Analyze basic operation of synchronous machines and determine their operating characteristics	1- determine the synchronous reactance 2- draw equivalent circuit of ac generators 3- interpret various levels of dc field excitation 4- control the flow of reactive and real powers 5- draw V-curves for different loading 5- use condensers for power factor correction	a,e, b,d	HW	3.35	3.38	Lab experiment to cover synchronous machines was introduced this time
			Labs	3.71		
			Final	3.07		
6) Ability to investigate an engineering problem and communicate results effectively	1) identify key factors involved 2) identify ways to save energy by improving efficiency 3) present results effectively	i,j, c,h, g	Assignments	3.49	3.61	No action required
			Reports	3.73		
7) Ability to work on teams to perform lab experiments and present results in the form of lab reports and team presentation	1) perform Lab experiments as a team member 2) collect and analyze data 3) submit formal lab reports 4) team presentation in front of an audience	g	Lab reports	3.73	3.63	Peer-evaluation & team presentation were performed in sp10 to improve meeting the soft skills of objective 7
			Presentation	3.50		
			Self-evaluation	3.67		

Table 7- Continuous Improvement Efforts (CIE) for Electric Machines Course	
Course Objectives	
1) Describe various types of DC machines and analyze their operating characteristics 2) Describe various types of single-phase motors and analyze their operating characteristics 3) Describe the various types of Transformers and analyze their operating characteristics 4) Describe various types of 3-phase induction motors and analyze their operating characteristics 5) Analyze basic operation of synchronous machines and determine their operating characteristics 6) Ability to investigate an engineering problem and communicates results effectively 7) Ability to work on team to perform lab experimentations, and present results in the forms of lab reports and team presentations.	Comparing meeting course objectives for Springs 08, 09, 10, reveals that soft skills in objectives 6 and 7 are met exceedingly well  Comparing Student Course Evaluation (SCE) with CLO evalutions show increased student confidence in meeting course objectives 

CONCLUSIONS

In this paper, we presented an effective assessment process that can be used by engineering programs to meet ABET student learning outcomes. This assessment process is carried out at both the program and course levels making use of direct and indirect measures. For each outcome, specific rubric with artifacts, benchmarks, and performance indicators were developed to gauge student performance across the curriculum. Based on the results of the assessment tools, continuous improvement actions were identified and used to revise the program assessment process. Furthermore, the course outcomes listed in the syllabus were also assessed and feedback from students was used to improve instruction. The assessment strategies presented in this paper may prove to be useful to other institutions seeking ABET accreditation.

REFERENCES

[1] Bollag, Burton, *Making an Art Form of Assessment*, The Faculty, The Chronicle of Higher Education, Washington D.C., October 26, 2006, pg. 8.

[2] Rahemi, Hossein and Seth, Naveen, "Student Learning Outcomes: An Integrated Continuous Improvement Process for Course and Program Assessment," *Latin American and Caribbean Journal of Engineering Education*, Vol. 2 (2), 2008

[3] ABET-Engineering Accreditation Commission, *Criteria for Accrediting Engineering Programs*, 2013-2014 Accreditation Cycle.

[4] Felder, R.M., Brent, R., "Designing and Teaching Courses to Satisfy the ABET Engineering Criteria," *ASEE Journal of Engineering Education*, Vol. 92 (1), 2003, pg. 7-25.

[5] S. Danielson, B. Rogers," A Methodology for Direct Assessment of Student Attainment of Program Outcomes", Proceedings of the 2007 ASEE Annual Conference, Honolulu, Hawaii, June 24-27.

[6] E. Rodriguez-Marek, M. Koh, C. Talarico,: Connecting the Dots in Assessment: From Course Student Learning Objectives to Educational Program Outcomes to ABET Assessment", Proceedings of the 2008 ASEE Annual Conference, Pittsburg, Pennsylvania, June 22-25

Youakim Kalaani

Youakim Kalaani is an Associate Professor of Electrical Engineering in the Department of Electrical Engineering at Georgia Southern University. Dr. Kalaani received his B.S. degree in Electrical Engineering from Cleveland State University (CSU). He graduated from CSU with M.S. and Doctoral degrees in Electrical Engineering with concentration in power systems. Dr. Kalaani is a licensed professional engineer (PE) and an ABET Program Evaluator (PA). He is a member of IEEE and has research interests in distributed power generations, optimization, and engineering education.

Rami J. Haddad

Rami J. Haddad is an Assistant Professor of Electrical Engineering in the Department of Electrical Engineering at Georgia Southern University. Dr. Haddad received his B.S. degree in Electronics and Telecommunication Engineering from the Applied Sciences University, Amman, Jordan. He received his M.S. in Electrical and Computer Engineering from the University of Minnesota Duluth, Duluth, MN. He received his Ph.D. degree from the University of Akron, Akron, OH. Dr. Haddad is a member in IEEE, OSA, CUR, and ASEE professional organizations. His research interests include various aspects of optical fiber communication/networks, broadband networks, multimedia communications, multimedia bandwidth forecasting, STEM education and engineering pedagogy.