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A Unified Approach to the Assessment of Student Learning Outcomes in Electrical Engineering Programs

Dr. Youakim Kalaani, Georgia Southern University

Dr. Youakim Kalaani graduated from Cleveland State University with MS and Doctoral degrees in Electrical Engineering with a concentration in power systems. He joined Georgia Southern University on August 2006 and is now an Associate Professor in the newly established Electrical Engineering Department at the College of Engineering and Information Technology. Dr. Kalaani has served as the Interim EE Chair and taught engineering courses at the undergraduate and garduate levels. He is a registered Professional Engineer and ABET Program Evaluator.

Dr. Rami Jubrail Haddad, Georgia Southern University

Rami J. Haddad is currently an Assistant Professor in the Department of Electrical Engineering at Georgia Southern University. He received the B.S. in Telecommunication and Electronics Engineering from the Applied Sciences University, Amman, Jordan, in 2004. He received his M.S. in Electrical and Computer Engineering from the University of Minnesota, Duluth, MN, in 2006. He received his Ph.D. degree from the University of Akron, Akron, OH, in 2011. His research focuses on various aspects of optical fiber communication/networks, broadband networks, multimedia communications, multimedia bandwidth forecasting and engineering education.

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Abstract

In this paper, a unified approach to the assessment of student and program learning outcomes to satisfy ABET and SACS accreditations criteria is proposed. This new approach takes into consideration the criteria of both accreditations to streamline the assessment process. As a result, a set of six skills categories were developed for SACS in which the eleven ABET student learning outcomes were embedded to satisfy both accreditation criteria. Furthermore, a standardized set of artifacts and rubrics were also developed to measure each skill category based on a given set of performance indicators. Data collected at the sophomore, junior and senior levels were recorded using a unified set of tables showing all the pertinent information needed to perform standard statistical analysis and to generate graphical presentation of the student performance at each level. For every outcome not meeting its benchmark, action plans were devised to address the shortcomings and close the loop on the assessment process. This novel approach was pilot tested this year for SACS and ABETS accreditations and has proved to be simpler and more efficient than any other assessment methods used.

Introduction

Nowadays, all engineering programs are expected to have some kind of accreditation required by government, graduate schools, and employers to ensure that students have the necessary skills to succeed after graduation. Accreditation agencies such ABET and SACS have established multiple sets of criteria or performance levels that an academic program has to demonstrate in order to be accredited. For instance, ABET is a professional accreditation agency that accredits individual engineering programs. It has put forward eleven student learning outcomes which cover basic skills like the ability to solve and design engineering systems to more advanced skills such as engaging in life-long learning and working on multidisciplinary teams[1]. On the other hand, SACS is a regional accreditation agency which accredits entire universities and not just an educational program like ABET does. However, SACS does not define specific learning outcomes for programs but it requires that they are specific, measurable, and support the missions of both the program and the institution. Furthermore, SACS appears to favor having fewer outcomes than ABET and encourage the use of direct measures as a tool for assessment. Therefore, complying with multiple accreditation criteria has become a daunting task for any engineering program since faculty and administration alike will have to engage in a complex assessment process that is both costly and time consuming[2,3]. Engineering programs seeking multiple accreditations are struggling to implement a unified assessment process[5]. To simplify the process, we propose to map the ABET student learning outcomes into six main skills that also map to our course level outcomes. For each skill, a specific rubric with artifacts, benchmarks, and performance indicators are developed to gauge student performance across the curriculum. In this paper, we present a unified assessment process that can be used by engineering programs to meet the requirements of ABET and SACS accreditation agencies.

Student Learning Outcomes

Student learning outcomes (SLOs) define what students should know or be able to do by the time of graduation. Those outcomes should be measurable and serve as benchmark assessments for completion of the program. Action verbs such as apply, analyze, interpret, and design are used in the SLOs statements based on Bloom's Taxonomy. Appropriate assessment strategies for each learning outcome must be identified along with a scoring rubric, target or criteria for success, measuring tools or artifacts, and the courses where assessment will take place. Using grades or student GPAs as criteria for success, are not accepted since these indicators do not provide sufficient information to guide program improvement.

While ABET has identified eleven a-k student learning outcomes in its Criterion 3 for accrediting Engineering Programs, SACS does not adopt particular outcomes but mandates that outcomes are meaningful, manageable, and measurable. SACS also encourage programs not to have more than six SLOs for effective assessment and to only use direct measures which sometimes present conflict with ABET outcomes which are more numerous and have no restriction on using additional indirect measures to assess the soft skills. Therefore, combining both SACS and ABET criteria into a unified assessment process is not a trivial task but can have tremendous advantage to any engineering program. To this end, the eleven ABET outcomes were used as performance indicators for the six SACS defined student learning outcomes. These SLOs identify the skills categories that Electrical Engineering (EE) students are expected to acquire upon graduation:

1- Basic Skills (SLO1)

- 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)

2- Design Skills (SLO2)

- 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)

3- Lab Skills (SLO3)

- 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)

4- Inquiry Skills (SLO4)

- Conduct research in electrical engineering discipline as part of life-long learning (i)

- Evaluate engineering systems as pertained to novelty and contemporary issues (j)

5- Profession Skills (SLO5)

- 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)

6- Communication Skills (SLO6)

- 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)

SLOs Assessment

The purpose of the assessment process is to develop a reliable and a consistent approach to assess student outcomes[6]. Developing an assessment process starts by identifying the student learning outcomes (SLOs)[4], then assessing whether the assessment process achieves these outcomes, and finally provides evidence of improvement based on the analysis of those results. In our EE program, the assessment of the student learning outcomes is based on the following direct and indirect measures:

a) Direct Measures
Student performance on exams, tests, and projects are used to measure specific performance indicators using scoring guides/rubrics designed[7]. There are at least three performance indicators for each a-k outcome as shown in Table 1.

b) Indirect Measures
These are surveys distributed to students, faculty, and the professional advisory committee (PAC). It provides feedback on whether the student learning outcomes are appropriate for the attainment of the stated program objectives.

Table 1 - Student Learning Outcomes Measures	
1-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
2-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,	• 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

Table 1 - Student Learning Outcomes Measures	
ethical, health and safety, manufacturability, and sustainability (c)	
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
3-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 contributes 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
4-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
5-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
6-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

Scoring rubrics were developed to measure student performance at five different 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

The rubric to measure Profession Skills (SLO5) is provided in Table 2 for reference:

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 the professions 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 our 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 simplify the assessment process and 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:

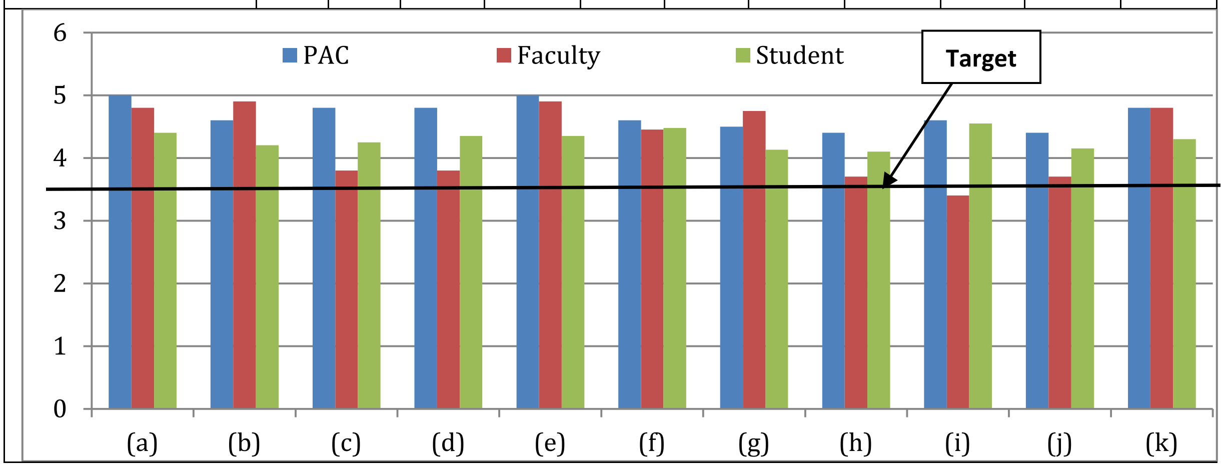
- "Developing" for the Sophomore Level (L1)
- "Proficient" for the Junior Level (L2)
- "Exemplary" for the Senior Level (L3)

Assessment Results

As stated earlier, the assessment process of student learning outcomes is based on direct and indirect measurements. Table 3 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."

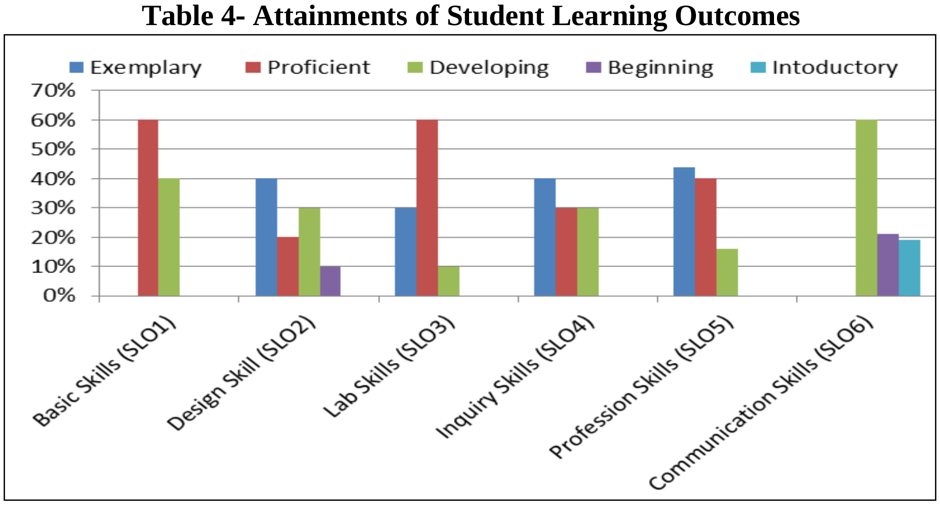
Table 3- Appropriateness of Student Outcomes to Achieve Program Objectives

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



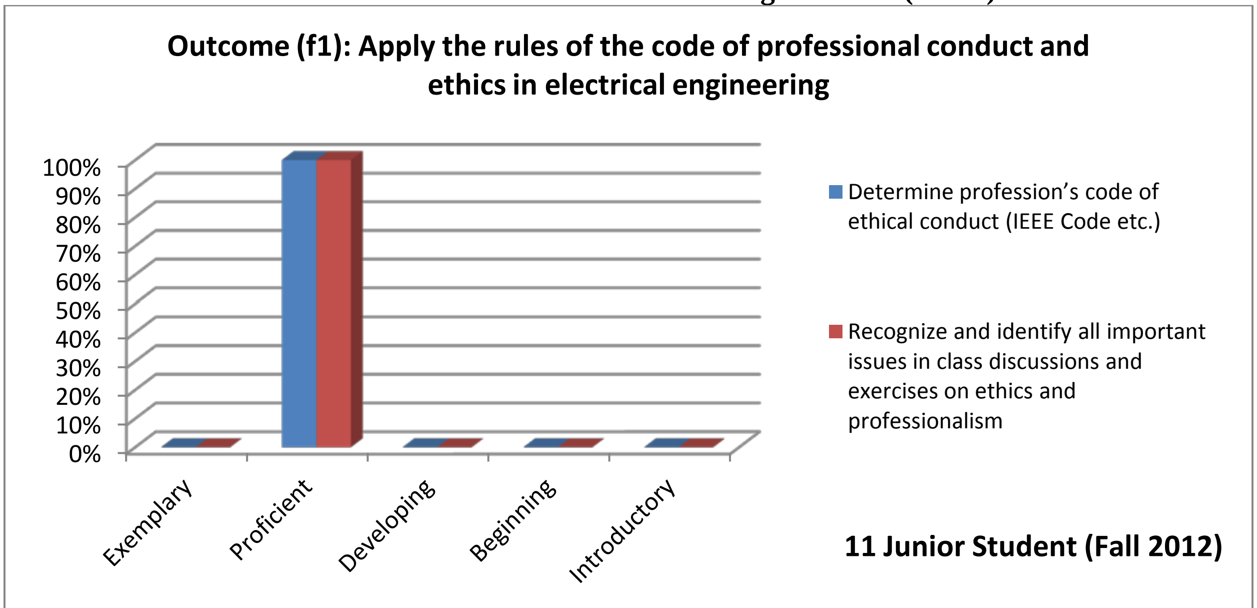
As for direct measures, the student learning outcomes were all measured with the results presented in Table 4 as a baseline for comparison in future assessment years.

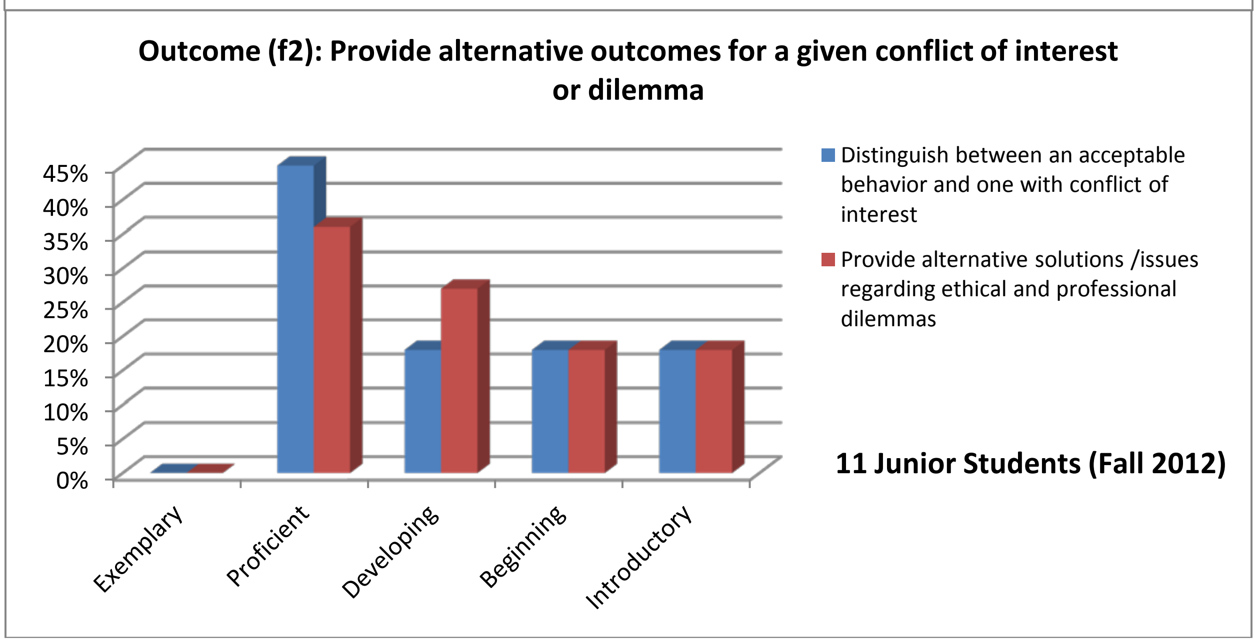
Table 4- Attainments of Student Learning Outcomes



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 Table 5. For instance, there were shortcomings in the performance indicators (f2) for which students in a study case assignment were not able to provide alternative outcomes for a given conflict of interests or dilemma dealing with ethics in the workplace and action plans were devised to address this issue.

Table 5- Attainment of Student Learning Outcome (SLO4)





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 analysis similar to the one shown in Table 6 where actions provided to improve instructions at the course level. The instructor also completes and submits a continuous improvement plan for each outcome measure that falls below the benchmark as shown in Table 7. Furthermore, a student course evaluation (plotted in Table 7) is an optional tool that faculty can use to improve teaching. It should be noted that many shortcomings are resolved at the course level, which in turn, contribute to the attainment of the student learning outcomes (SLOs).

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		Mean(Actual Level 2/4)	Observation/ Recommendation/ 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 Labs Exam1 Final	3.35 3.73 2.89 2.70	3.17	Students are not performing well on Exams
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 Labs Exam2	3.35 3.73 3.71	3.60	No action required
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 rating 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 Labs Exam2 Final	3.35 3.73 3.71 3.19	3.49	No action required
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 Labs Exam3 Final	3.35 3.73 3.54 3.40	3.50	The equivalent circuit of an induction motor was introduced this time
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 Labs Final	3.35 3.71 3.07	3.38	Lab experiment to cover synchronous machines was introduced this time
6) Ability to investigate an engineering problem and communicate results effectively	1) Identify key factors involved 2) Identify ways to improving efficiency 3) Present results effectively	i,j,c,h,g	Assignments Reports	3.49 3.73	3.61	No action required
7) Ability to work on teams to perform lab experiments and present results in the form of lab reports and 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 Presentation Self-evaluation	3.73 3.50 3.67	3.63	Peer-evaluation & team presentation were performed in sp10 to improve meeting the soft skills of objective 7

<table>
<tr><th colspan="2">Table 7- Continuous Improvement Efforts (CIE) for Electric Machines Course</th></tr>
<tr><th>Category of Continuous Improvement</th><th></th></tr>
<tr><td>Which course content areas do you feel students grasped well? Why? (For example, instructional methods used, thorough explanation in textbook, incorporated supplemental tools on topic, etc.)

<u>Course Objectives</u>:

1) Describe various types of DC machines and analyze their operation 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

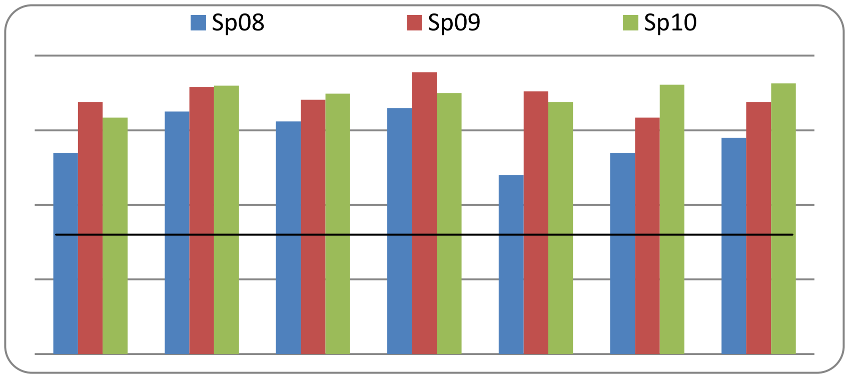
4) Describe various types of 3-phase induction motors and analyze their operating characteristics

5) Analyze basic operation of synchronous machines and determine their operating characteristics

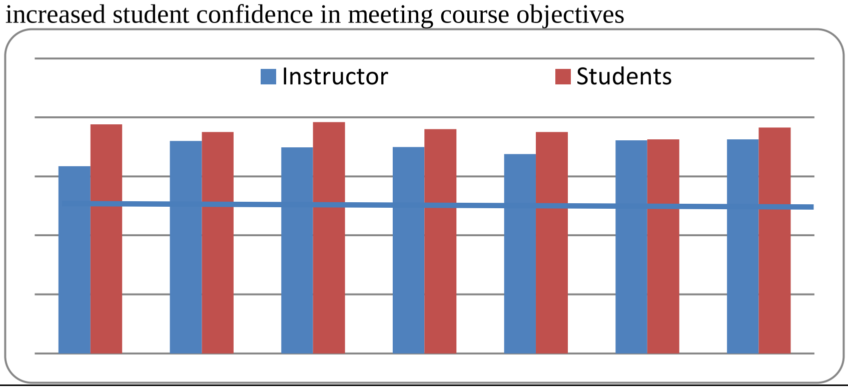
6) Ability to investigate an engineering problem and communicates results effectively

7) Ability to work on team to perform lab experimentations, and present results in the forms of lab reports and team presentations.</td><td>- No action required this time for objective 1 which was flagged in sp09
- The equivalent circuit of an induction motor was introduced in sp10
- Lab experiment to cover synchronous machines was introduced in sp10 to support student learning
- Peer-evaluation and team presentation were performed in sp10 to improve meeting the soft skills

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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Conclusions

This paper presented a unified approach to the assessment of student and program learning outcomes to satisfy ABET and SACS accreditation criteria. A set of six skills categories were developed for SACS in which the eleven ABET student learning outcomes were embedded to satisfy both accreditation criteria. Furthermore, scoring guides and artifacts were used to measure each skill category based on a given set of performance indicators. Data collected at the sophomore, junior and senior levels were used to perform standard statistical analysis and to generate graphical presentation of the student performance at each level. For every outcome not meeting its benchmark, action plans were devised to address the shortcomings and close the loop on the assessment process. In addition, 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 was pilot tested in 2013 and may prove to be useful to other institutions seeking SACS and ABET accreditations.

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