Teaching Energy Conversion – A Case of Electrical Engineering Students Self-Assessing Performance Outcomes

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Abstract – This paper deals with analyzing student performance outcomes of an electrical engineering core-course in energy conversion by tracking student perceptions and correlations with changes in delivered technical content between 2008 and 2010. Outcomes from the final comprehensive exams were compared to the student self-assessment survey results. The outcome assessment was done based on performance in questions relating to (1) dc motors and electromechanical energy conversion system principles, (2) ac machines and power flow diagrams, (3) transformers and equivalent circuits, and (4) three-phase circuits. The student self-assessment surveys given prior to final exams combined the concepts taught in the course and general feedback on the course instruction. The questions included a measure of confidence in applying basic principles learned in the course and identifying different systems to apply the electromechanical energy conversion principles. The analysis also checks the potential validity of self assessments as a formal assessment instrument.

Keywords: electrical engineering, energy conversion, assessment.

INTRODUCTION

The purpose of assessments and evaluation are to help in identifying program areas of growth and focus plans for improvement in certain areas of instructional performance and more importantly, measure whether students are learning. Students and faculty involvement is pivotal in meeting educational program objectives and course learning objectives through assessment and evaluation [1] [6]. Current students are inundated with abundant activities inside and outside the classrooms leaving them with limited knowledge on the effect of their participation on the improvement of curriculum as well as letting the faculty know the learning methods they prefer. However, once the students are engaged in the process of their education on the input objectives as well as the output results, it will help put the importance of student program outcomes in perspective.

Although the measurement of course outcomes based on student self-assessments are considered to be valid [5], Newcomer's results indicate that the students tend to over predict their abilities [4] and concludes that students have a limited ability to predict how well they are prepared for exams or have performed on exams [3]. Sarin concluded that there is significant validity of student self-assessments and justification in the use of student self-assessments in formative nature [5]. In addition, previous conclusions are that competent students provide more accurate self-assessments.

This paper looks at student self-assessments and student performance outcomes in an electrical engineering core-course in energy conversion by tracking student perceptions and correlations with changes in delivered technical content between 2008 and 2010. Outcomes from the final comprehensive exams were compared to the student self-assessment survey results. The course content features (a) fundamentals of electromechanical energy conversion, (b) transformers, (c) ac/dc motors and generators, and (d) transient analysis of electric machines. The exam questions were in the following categories (1) dc motors and electromechanical energy conversion system principles, (2) ac machines and power flow diagrams, (3) transformers and equivalent circuits, and (4) three-phase circuits. The corresponding student self-assessment surveys given before final exams combined the concepts taught in the course and general feedback on the course instruction. The questions included a measure of confidence in applying basic

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principles learned in the course and identifying different systems/applications to apply the principles. In addition, the students' assessments were a measure of their course expectations and perceptions of course assessment material throughout the semester.

BASIC ENERGY CONVERSION COURSE CONCEPTS

The generic course description of the energy conversion course includes fundamentals of electromechanical energy conversion, transformers, motors, generators, and transient analysis of electric machines. The teaching of energy conversion and electric machines has evolved over the years. The energy conversion course was originally focused on macro-electromechanical energy conversion and in 2008, course integration of micro-electromechanical energy conversion systems started. The electric drive model was adopted for teaching the course. Course material covers fundamentals of electric machines as energy converters. The focus is on basic structures of electric machines along with the principles of electromagnetic interactions governing the energy conversion process. The two general concepts are: 1) on the production of the electromagnetic force, f_{em}(Nm), on a current carrying conductor when the conductor is subjected to an externally-established magnetic field and 2) on induced electromotive force, e (V), on a conductor moving in a magnetic field such that: [2].

$$f_{em} = BiL \quad \text{(Equation 1)}$$

$$e = BLu \quad \text{(Equation 2)}$$

B is magnetic flux density measured in Tesla (T), *i* is current in amperes (A), *L* is length of conductor in meters (m), and *u* is the speed of the conductor through the magnetic field. In addition to teaching the mathematical and physical definitions of force components, the concepts are also emphasized with the use of Fleming's left and right hand rules for equation 1 and equation 2 respectively. The thumb represents motion (force), pointing finger for magnetic flux, and the middle finger for current direction. The conversion of energy and efficiency is also introduced in this section by following the power flow from electrical to mechanical and vice-versa.

The experience in teaching this course has shown that students tend to have limited understanding of three phase circuits and transformers; as a result, prior knowledge in the subject of transformer principles, equivalent circuits, and three phase circuits is no longer assumed in this course. The principle of transformers is explained as the gateway to understanding motors and generators especially through the development of equivalent circuit models. The knowledge of the transformer equivalent circuit model makes generating equivalent circuit models for motors and generators less daunting to students. The models make it easier for students to recognize energy losses during the energy transfer process. Transformer configurations are used in explaining three-phase circuits (wye and delta configurations) as well as show the transfer of power and calculation of power quantities; apparent power, real power, and reactive power. The use of phasor diagrams relating power quantities is also taught.

The structure and construction of motors and generators is discussed including the equivalent circuit models. The knowledge derived from transformer principles is directly applied. Spending significant time on transformers and three-phase configurations seems to help students in understanding the three phase nature of these electromechanical systems. Transient analysis of transformers and motors highlighting different operating conditions are highlighted. Concepts dealing with torque/speed control characterizations are the focus in transient analysis of electric motors.

SELF ASSESSMENTS AND PERFORMANCE OUTCOMES

The course's generic assessment for the grade is based on homework, quiz, exams, and a comprehensive exam at the end of the semester. The self-assessments surveys were employed over a period of 3 years to help gauge the effectiveness of formal assessments and measure the effect of course changes to the student's performance. In these self –assessment surveys, the direct pointed questions based on learning objectives and effectiveness of the approach used in the course are asked. The survey also helps in putting the students' understanding of the curriculum into perspective by asking pointed questions on prerequisites and co-requisites. Students are allowed to respond on the surveys by stating some of their preferred learning styles reflecting on homework, quizzes, projects, and exams as well as the way the lectures are conducted. Their opinions are also indicated by what they believe are important concepts they learned, their biggest challenges, and their suggestions for improving the course. Tables 1-3 show the self assessment survey used in capturing the information.

Table 1: Part 1 of Self Assessment Survey – Binary Response

Questions	**Response**	**Comment(s)/Explanation**
1.1. Did the syllabus clearly identify the learning objectives for this course?	Yes/No	
1.2. Were the prerequisites and corequisites helpful in this course?	Yes/No	
1.3. Would you suggest any other prerequisites for this course?	Yes/No	
1.4. Do you feel confident in applying basic principles of the law of induction in the principle of operation for electromechanical energy conversion systems?	Yes/No	
1.5. Can you identify different electromechanical systems (transformers, induction motors, AC synchronous motors & generators, DC motors & generators?	Yes/No	

Table 2: Part 2 of Self Assessment Survey – 4 Point Likert Scale
(4 – Agree; 3 – Somewhat Agree; 2 – Somewhat Disagree; 1 – Disagree)

Questions	**Response**	**Comment(s)/Explanation**
2.1. Did the material covered in the course match your expectations?	4 3 2 1	
2.2. Were the homework problems assigned helpful in understating the material?	4 3 2 1	
2.3. Were the homework solutions and reviews sufficient?	4 3 2 1	
2.4. Do you think quizzes reflected the material covered during lectures and HW?	4 3 2 1	

Table 3: Part 3 of Self Assessment Survey – Open Responses

Questions	**Comment(s)/Explanation(s)**
3.1. What was the most important thing you learnt in this course?	
3.2. What was the biggest challenge in this course?	
3.3. What suggestions can you offer about improving the course?	

Questions on the survey helped measure the students' confidence and opinion. For example, questions on the knowledge of the application of the law of induction in the principle of operation for electromechanical energy conversion systems as well as identification of different electromechanical energy conversion systems and components were asked as shown in Table 1. The survey responses were compared against comprehensive examination performance that tested on the corresponding knowledge. Table 2 shows opinion survey questions on lecture material delivery, homework, quizzes, and exams using a 4-point Likert scale (Table 2). Responses where no answers were given, an N/A response was assigned. The open opinions in Table 3 indicated what the students believed were important concepts they learned, their biggest challenges, and offered their suggestions for improving the course.

Survey responses to 6 questions are reported in this paper. Survey questions1.4 and 1.5 are on the course knowledge base, whilst questions 2.1 to 2.4 are on course material delivery and assessment methods measured against the student's expectations. The comprehensive exam questions were grouped into one of the 4 categories: (1) dc motors and electromechanical energy conversion system principles, (2) ac machines and power flow diagrams, (3) transformers and equivalent circuits, and (4) three-phase circuits. The performance evaluation outcome was based on how well the student did in each category. A 75% or better score on any question category was considered satisfactory knowledge in that category. For example, if category 1 questions were graded out of a score of 20, a score greater than 15 will be considered to be satisfactory and designated a response equivalent to an Agree on the 4-point Likert scale. Agree implies that the student's performance is satisfactory. As a result, Table 4 shows the equivalent scale that was used in analyzing the comprehensive exam questions. This scale implies that the students who responded with a YES to questions 1.4 and 1.5 were expected to score above 75% in order for the response to be comparable; however, the analysis also differentiates between those students whose performance is marginally satisfactory from those who had unsatisfactory performance.

Table 4: Performance Outcome Scale

% score per question category	Response Scale
≥75%	Agree
60≤Score<75%	Agree Somewhat
40≤Score<60%	Disagree Somewhat
<40%	Disagree
Not Answered	N/A

PERFORMANCE RESULTS

Generally, the energy conversion course has an average of 12 students, however, in 2008 there were only 6 students enrolled in the course. The few students allowed for a variety of informal assessments during class including questions on their learning style preferences, study habits, and expectations among others. At the end of the semester and subsequent years a survey to capture the students' responses on various questions that could affect performance in the course along with their suggestions and performance expectations was administered. Figure 1 shows the survey results extracted from part 2 of the self-assessment survey. A total of 32 students were surveyed over the three year period.

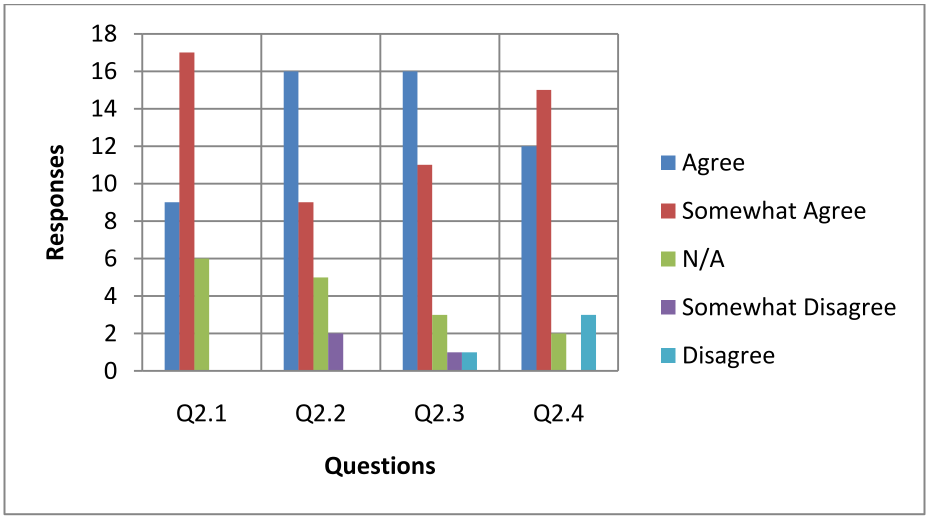

Figure 1: Overall self-assessment survey on student perceptions

The general perceptions of the students captured by the surveys indicated satisfaction with the formal assessment methods. Figure 1, shows that over 84% of the students were marginally in agreement or fully in agreement on the homework and quiz assessments used in the course. 81% responded that the course matched their expectation. Self-assessments on course performance outcome were also evaluated through responses to part 1of survey questions Q1.4 and Q1.5. Figure 2 responses to Q1.5 shows that over 80% have confidence dealing with basic principles of electromechanical energy systems; however, only 75% agreed that they thought they could confidently apply the basic principles in the operation of energy systems.

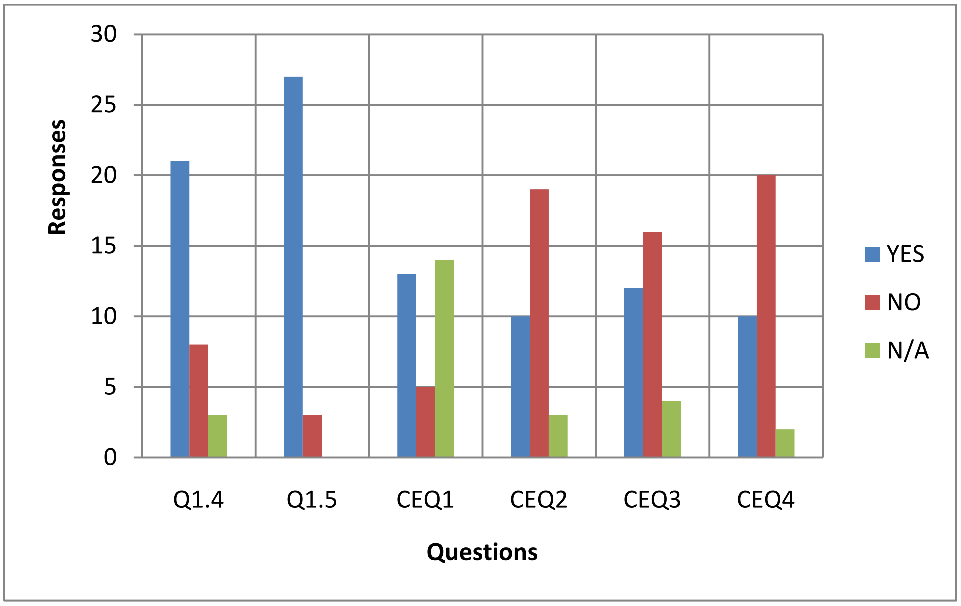

Figure 2(a): Overall self-assessment survey and comprehensive exam responses

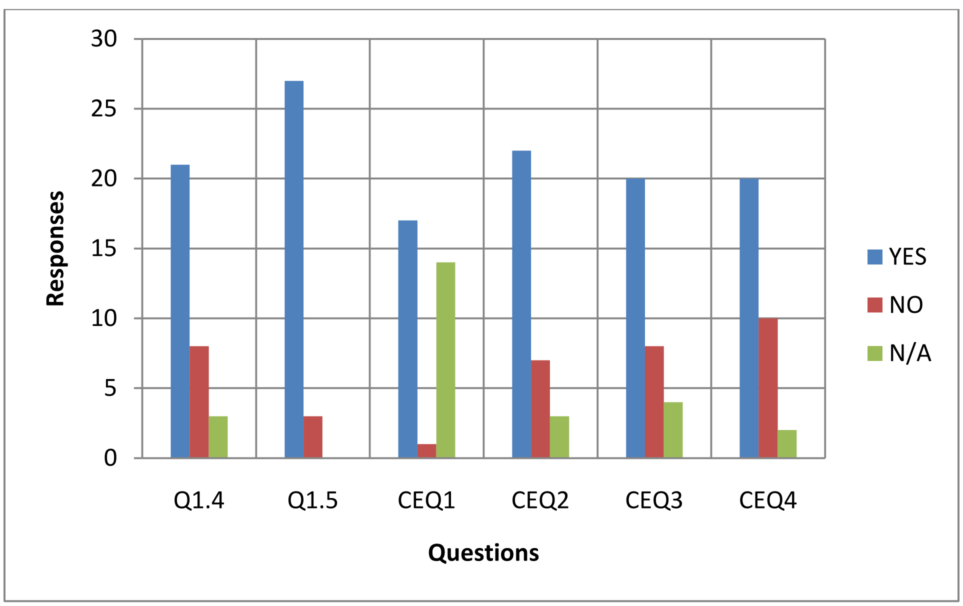

Figure 2(b): Overall self-assessment survey and comprehensive exam responses (marginal)

The perceptions of the students measured in Q1.4 and Q1.5 were evaluated in comprehensive exams using a select set of questions labeled in the following categories:

- CEQ1 – dc motors and electromechanical energy conversion system principles
- CEQ2 – ac machines and power flow diagrams
- CEQ3 – transformers and equivalent circuits
- CEQ4 – three-phase circuits

There was an expectation for the responses on the exam questions to follow patterns established on the self-assessments surveys, but results shown on figure 2(a) are quite different. The response results on figure 2 are based on the table 4 scale. This implies that according the comprehensive exam results outcomes in figure 2(a), an average of 46% of students scored at a satisfactory level. Further analysis combined satisfactory level and marginal level (agree and somewhat agree) as shown in figure 2(b). This resulted in an average of 77% responding students receiving a YES satisfactory score. The students rated themselves slightly high than the comprehensive examination evaluated scores of select questions. In consideration of the overall class performance, the students' self-assessment is probably a more accurate measure of the course performance judging on the course grade trends. Since there is no identifying information collected on the surveys, the overall course grade correlation to the self-assessment response will remain a speculative based on the fact that 90% of the students received a satisfactory grade for the course during the study period.

CONCLUSION

This study shows that comprehensive final exams should probably be used with other mid-semester assessment tools such as homework and quizzes among others to evaluate the performance outcomes. The student self-assessment tool could also be considered as an outcome assessment tool. Whenever a significant change is made to a course, student self-assessments could be good indicators of the effectiveness of the changes as well as help in quickly overcoming weaknesses that might result from instructional changes. The results of self-assessments performed over a period of 3 years have indicated that the approach could be beneficiary to the evaluation of course outcomes and learning objectives due to the general self-assessment response correlation with actual performance outcomes. However, further study is still warranted due to the limited sample data as a result of small class sizes. Another indicator of performance outcome measurement could be the level of satisfaction the student deem to have in reference to their expectations. In overall, self-assessments could be valid as formal assessment instruments; however, their use is best in a formative assessment role.

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