Assessment of Student Learning Outcomes and Student Self-Assessment in an Undergraduate Controls Lab in Mechanical and Aerospace Engineering

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Abstract

In a review of course objectives in an undergraduate controls course, students were asked to take an assessment, which covered some questions on the topics of digital and analog signals and controls, as well as a self-assessment of student confidence in their knowledge. The assessment was taken once prior to covering advanced analog control topics and the digital controls topics, and again after the course was complete. Analysis of results show student learning on most topics increased, there was a significant change in the student self-assessment, where more students ranked their skill level at a higher level. While the percentage of students who correctly answered the question generally increased between the pretest and post\ test, the student self-assessment scores were not good indicators of whether students were going to answer questions at the higher-level evaluation questions correctly.

Keywords

Electronics, Mechanical Engineering, Aerospace Engineering, Laboratory

Introduction

In the curriculum of the Department of Mechanical and Aerospace Engineering at North Carolina State University, undergraduate students are required to take a course, MAE 405, Controls Lab. The course description states the course covers, "Laboratory experiments demonstrate the essential features of classical and modern control theory for single-input and single-output systems."[1].

For this course, there is a separate, 1 credit hour, undergraduate lab, where students conduct hands-on experiments in analog and logic based control systems, including basic electronics, analog Proportional Integral Derivative controllers, and industrial Programmable Logic Controller systems. As shown by Freeman et al. [2], the inclusion of active learning in a curriculum improves student understanding of STEM based material. The course consists of 9 experiments focusing the analysis of analog circuits, from simple circuits to analog PID control, and digital control methods through industrial PLC's. Experiments in analog circuits focus on observing behavior of a system and analyzing those observations based upon theoretical results. Digital controls is taught on an evaluation/ creation level, having students observe the behavior of a physical plant, then evaluating the actions necessary to complete a certain task, and writing a program for the task.

Based on questions posed in Feisel et al. [3], it is necessary to continually assess the fundamental objectives of a lab based course, and highlight key questions to address in the redevelopment. As mentioned in the study, the fundamental engineering laboratory objectives are using instrumentation, qualifying scientific models, apply experimental methods, collect and interpret data, demonstrate the design process, learning from failure, foster creativity, show competence in engineering tools, show laboratory safety, improve effective communication, progress teamwork skills, reinforce ethics, and form sensory awareness for engineering judgement [3]. These fundamental objectives directly relate to the ABET outcomes for the MAE department.

Methodology

The focus of this study was the initial assessment of the course objectives for redevelopment of course experiments, similar to Alleyne et al. [4], focusing on developing small scale, inexpensive experiments. While other courses within the MAE have undergone assessments similar to the student opinion based assessment mentioned in Schkoda et al.[5], but due to the advanced nature of most of the topics covered in MAE 405, a review based upon student learning objectives and concepts was chosen. During this semester, an analysis of student understanding of concepts in MAE 405 was conducted. The students were assessed on:

Table 1- Assessment Questions for MAE 405

Topic	Topic Area	Action
Basic Analog Signal Identification	Analog Signals and Control	Determine which choice was an analog signal
Basic Digital Signal Identification	Digital Signals and Control	Choose which signal is a digital signal
Operation Amplifier Gain ID	Analog Signals and Control	Calculate the gain value of a simple gain circuit
Operational Amplifier Circuit Problem Diagnosis	Analog Signals and Control	Given a similar circuit to the Op-Amp gain ID problem, with a fault built into the system (Figure 2)
PLC Basic Ladder Logic	Digital Signals and Control	Determine the result of activating a ladder logic input
PLC Advanced Ladder Logic	Digital Signals and Control	Given a set of initial conditions, what conditions are necessary to activate a specific output

Table 1 consists of an explanation of each one of the questions used in the assessment questions. The assessment consists of 6 questions on topics covered in the course, shown above, as well as, 2 self-assessment questions, where students are asked about their level of confidence in 2 topic areas; analog signals and digital signals. Then number of respondents was 104 for the pretest and 88 for the post test.

Data and Analysis

The assessment was given prior to the PID Controller construction lab (lab 5) and again after the Industrial PLC platforms lab (lab 10). A breakdown of the initial assessment is shown below, where each question gave the students the option to choose “I don’t know”. It should be noted that while analog circuits is covered earlier in MAE 405, as well as a previous labs., but the application digital signals is not presented any conventional lecture course, and is shown in technical electives and in the MAE 405.

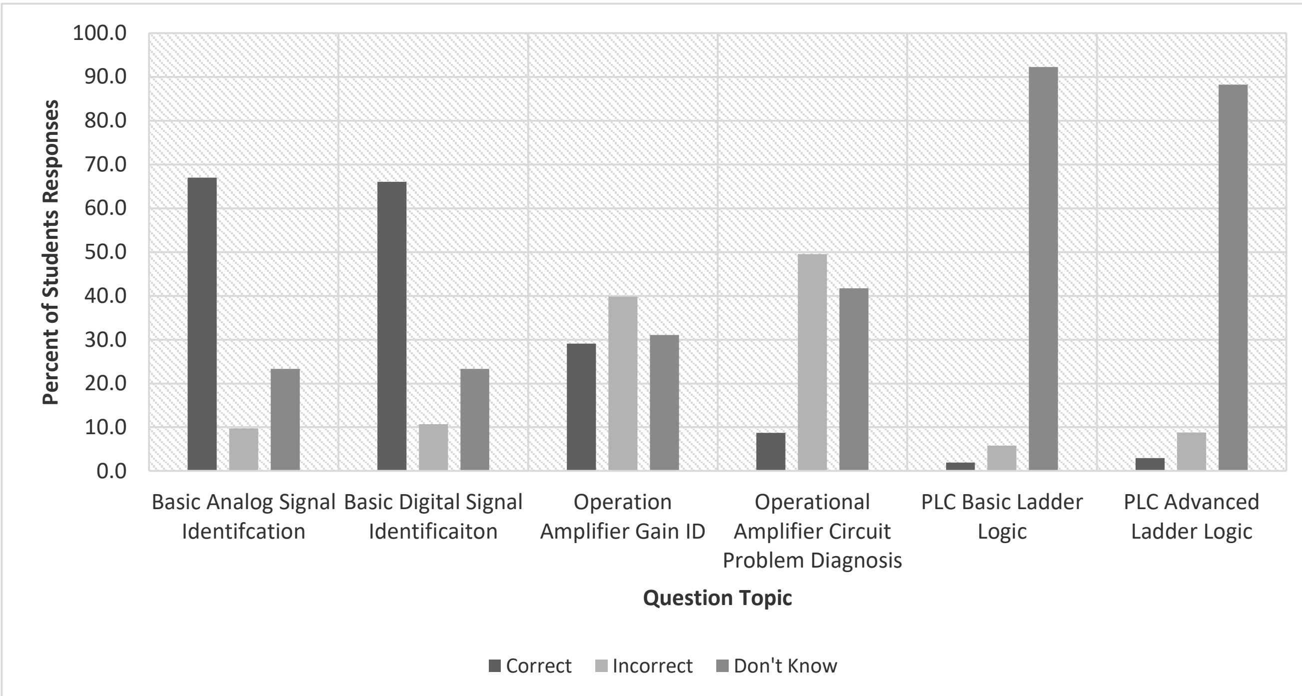

Figure 1- Assessment of MAE 405 Student Comprehension- Pretest

As shown in Figure 1, the students are able to correctly identify an analog or digital signal, but as the level of knowledge increases past the baseline learning comprehension, going into understanding and analysis, causes significant decreases in the number of students who correctly answer the question. Of note is the operational amplifier circuit problem diagnosis assessment, the students were presented with the following problem,

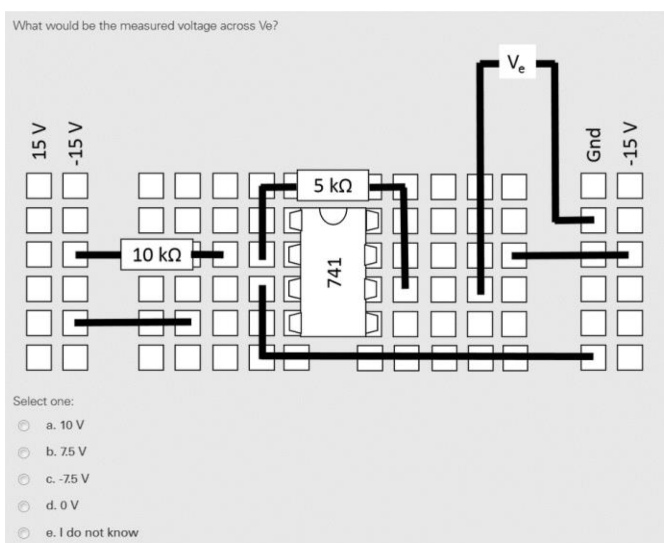

Figure 2-Amplifier Circuit Problem Diagnosis Assessment

Based upon the layout of the circuit shown in Figure 2, the circuit should output an electric potential of 0V (relative to ground), as an operational amplifier requires both a positive and negative supply voltage to operate. Most students were able to properly identify that with the resistor combination would result in a

½ gain circuit, with inversion or without, but were not able to spot the fault in the circuit. This shows a major concern within the Mechanical and Aerospace Engineering. lab courses, where students have a significant difficulty in critical thinking of electronic materials, in particular, and in troubleshooting.

After the final PLC lab, the students were posed the same questions. The results shown below, as well as a comparison of the pretest results to the post-test results.

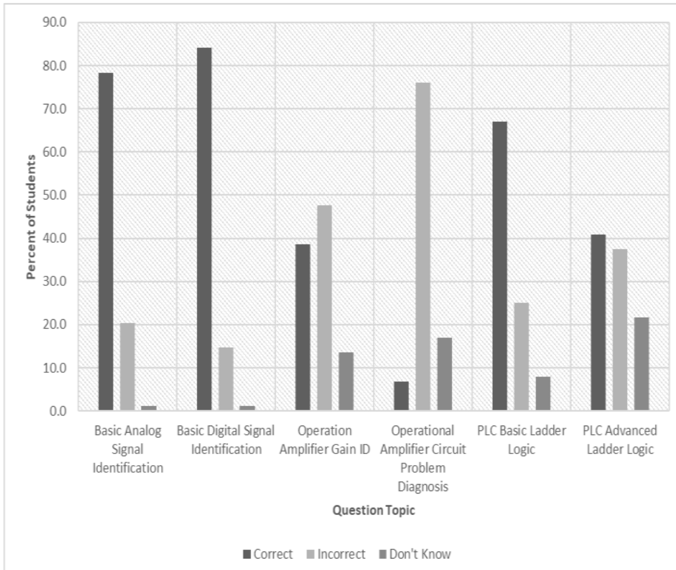

Figure 3- Assessment of MAE 405 Student Comprehension- Post-Test

The first observation from the assessments from the pretests and the post-tests, is that more students attempted to answer the question, rather than defaulting to the "I don't know" response, especially in the operational amplifier gain identification, onwards. The other significant observation is the increase in correct responses for the PLC basic ladder logic and advanced ladder logic questions, which shows the percent change in correct responses between the pretest and post-test, where the PLC questions have a 62.2% and 38.0% increases between the pretest and post-test.

The second part of both the pretest and post-test was having the students comment on their own perception of their level of knowledge, rating themselves on a scale from "very poor" to "very strong" in both analog and digital signals and control. The results for the pretest and post-test are shown below, where the students showed a marked increase in their assessment of their knowledge and skills.

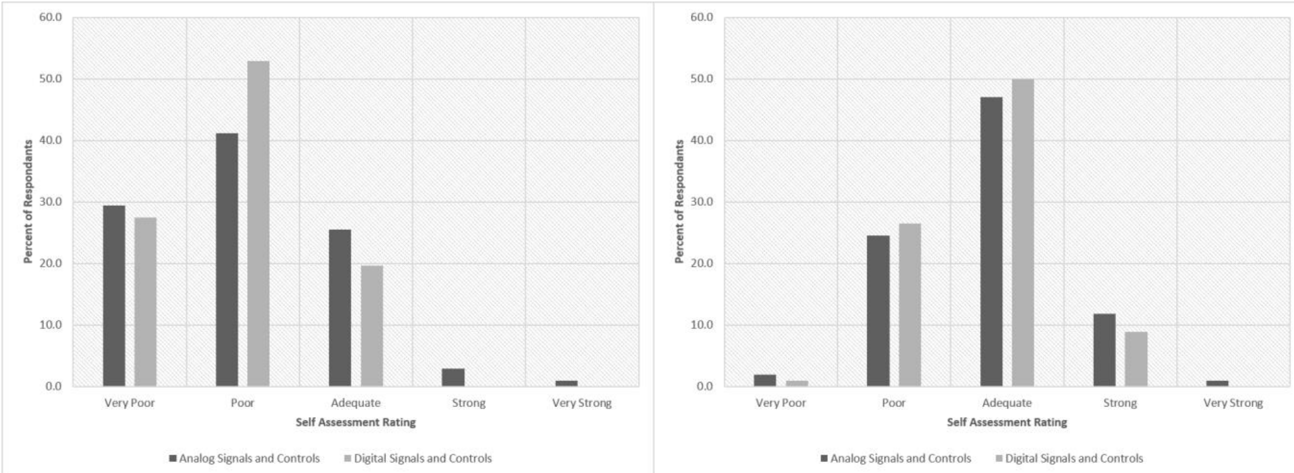

Figure 4- Students' Self-Assessment of Knowledge of Pretest (Left) and Post-Test (Right)

As shown in Figure 4, the most common response went from a rating of "poor" on both analog and digital signals and controls to "adequate". A significant improvement within the course is seeing that a significant number of students see an increase in their understanding of both major topics within the course. Also of note is the fact that there were no students rated themselves in the "strong" or "very strong" in digital signals in the pretest. It is generally assumed that there will be a student or two in a large class who have been exposed to this material, especially for a senior level lab, through an internship or co-op, but the students appeared to rate themselves lower, possibly as a result of having no formalized lecture or classroom activities around a subject, which can be demonstrated by Figure 1. Prior to labs 9-10, students had not be formally introduced to PLC's in the MAE curriculum, yet 5 students correctly responded to the basic PLC questions, and 3 were correct on the advanced PLC question, in the pretest questions.

An interesting observation can be made when combining, the results of the self-assessments with the results of the questions. In Figure 5, the scores of each question are broken down based upon the self-assessment scores.

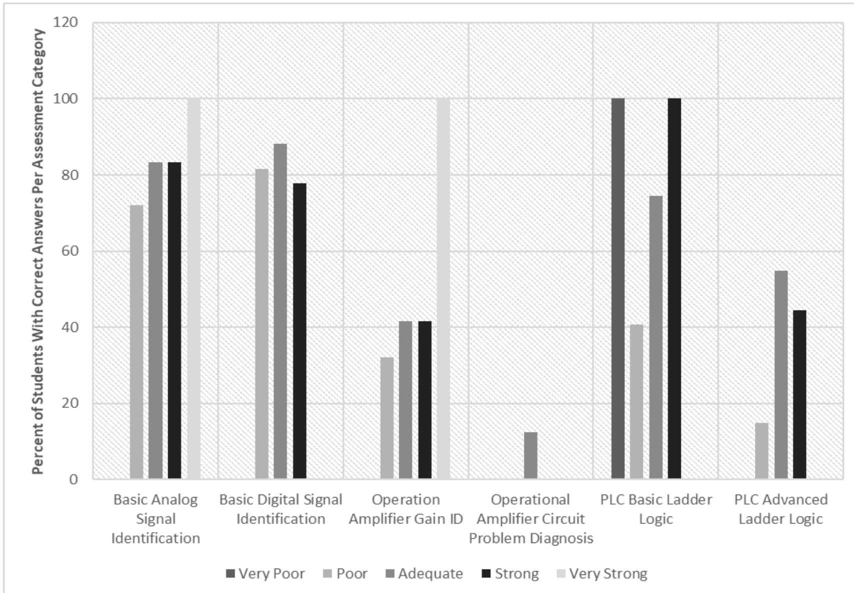

Figure 5-Student Achievement Compared to Self-Assessment Scores from Post-Test Results

In Figure 5, the first questions on signal identification followed expected trends, with students, who rated themselves as on the lower end of the competency scale, had a lower likelihood of answering the question correctly. Yet, once the questions reached a higher level of difficulty, beyond simple understanding, the student assessments were not an indicator of the probability of having a correct answer, with none of the students who rated themselves higher than adequate in analog controls were unable to answer correctly the op-amp problem diagnosis circuit, which required the evaluation of the circuit in a real world situation. Even when covering the digital content, with the two questions on PLC content, did not fit with expected trends, likely due to exposure effects, such as the Dunning-Kruger effect [6]. The Dunning-Kruger effect [6], as described by Justin Kruger and David Dunning, is the combination of the ability of relatively unskilled novices to reach incorrect conclusions, and their lack of experience to realize that they are novices and might be prone to making mistakes.

At the time of the tests, the students were only just being exposed to this material; most were concurrently taking a lecture course covering these topics. Based on a very limited period, for most, a single semester of exposure, students began rating themselves as strong or very strong in both topics, including digital controls, where in the undergraduate program there is a small amount of coursework and lab material in the topic. Based upon these observations, it is apparent that students need to be shown that there are significantly more topics that could not be covered in a survey course and lab courses, which could be accomplished through significant additions of design challenges, covering the higher levels of the revised Bloom's taxonomy[7,8]. The course objectives mainly focus on the analysis tier Having students exposed to more evaluation and creation opportunities will allow them to, not only gain significant experience in design skills, but also allow them to gauge their level of expertise in a realistic setting.

Conclusions

In an assessment of a mechanical and aerospace engineering undergraduate controls course at North Carolina State University, students were given a set of questions to gauge their understanding of digital and analog signals and controls, including having students consider their own level of understanding in these topics, in pretest and post-test quizzes. It was found that;

- Student understanding of most topic areas increased after students completed the course material on digital controls.
- Student self-assessment scores increased after the course material was covered
- The number of students who attempted the questions, rather than responding with “I do not know” responses, increased
- On advanced topics in analog and digital controls, requiring higher level analysis or evaluation skills, the student self-assessment scores were not good indicators of the probability of the correct results on the assessment questions

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