AC 2008-1959: CONTINUOUS IMPROVEMENT IN ELECTRICAL ENGINEERING STUDENT OUTCOMES

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Continuous Improvement in Electrical Engineering Student Outcomes

Abstract

Continuous improvement in the sophomore-level electrical engineering course outcomes and junior-level entrance exam outcomes has been studied at Western New England College. Data has been tracked over a four year period and continuous improvement of students' knowledge retention between the sophomore and junior-level years has been demonstrated. This paper addresses the methods and curricular changes implemented to affect the improvement. The effects of the curricular changes made in the sophomore-level electrical engineering courses are also analyzed and presented.

Background

Among engineering educators, it is well known that the ABET accreditation process requires engineering programs to demonstrate that they have a continuous improvement methodology in place. Many authors have documented their programs' continuous improvement efforts and feedback loops. Much of this literature discusses program outcomes and the program level feedback loops[1,2,3,4,5]. Other authors discuss continuous improvement feedback loops for individual courses[5,6,7]. Additionally, some authors provide a great deal of insight and detail about proper course design and delivery to satisfy the ABET Engineering Criteria[8]. These authors[8] focus on how to equip students to better achieve the specified course outcomes. There are few papers that focus on tight feedback loops between sequential core courses. This paper will discuss a feedback loop between the core sophomore circuits courses and the first portion of the junior-level microelectronics course.

Introduction

All sophomore electrical and computer engineering students at Western New England College are required to take a two-semester linear circuits sequence. As juniors, these students must also take an introductory microelectronics course. Prior to the Western New England College's first ABET accreditation cycle under the EC2000 guidelines, the microelectronics professors approached the linear circuits professors to discuss deficiencies in the skills of the junior-level students. Over the next few years, several meetings were held between the sophomore and junior level instructors with the purpose of discussing competencies that needed improvement and methods to affect continuous improvement in these competencies.

Methods for Continuous Improvement

Communication is very important in any feedback loop. In the case here, communication between the junior level and sophomore level instructors is discussed. Successful completion of the course outcomes from the sophomore class, in theory, should prepare a student for his/her junior year. It was found, however, that even though the sophomores had successfully completed their course work, they were not as well prepared for junior year as the junior level instructors expected them to be. Knowledge retention was identified as one of the key problems in the students returning to their junior year after their summer break. When the faculty discussed the outcomes from the sophomore linear circuits courses and the knowledge of the junior students, there seemed to be a huge disconnect. There was noticeable knowledge loss over the summer break. It is well documented that knowledge retention decays over time[9]. Therefore, in the feedback discussions, faculty brainstormed ideas for refreshing the memories of the junior level students. The first key change at the course level of the junior microelectronics was the requirement of summer homework. It was believed that students who did their summer homework, would have better knowledge retention. Thus, over the summer, students were required to do homework problems similar to those shown in Figure 1 and to bring those problems with them to the first class of the microelectronics course.

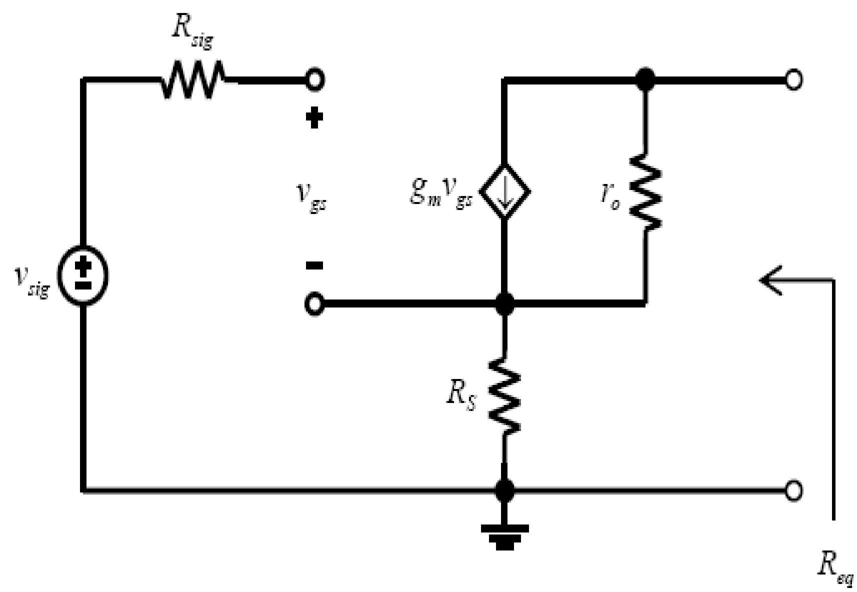

Figure 1: Example summer homework problem.
"Derive and expression for the resistance, Req, for the small-signal circuit."

This homework was graded and returned to the students. If they did not do well, they were given additional problems to complete. About a week later, the first quiz was administered. The results of this initial change showed marked improvement in the student's scores on the first quiz and exam of the microelectronics course. Details of the improvement are discussed in the results section.

After the first feedback cycle, a year later, the professors met for a second round of discussions to find further improvement techniques. This discussion brought to light one of the major differences found between the sophomore and junior level courses – other than s-domain analysis, which was briefly covered at the end of the sophomore year, the sophomore level courses did not require much symbolic problem solving. Most of the circuits solved at the sophomore level were numeric in nature and could easily be solved using the simultaneous equation solvers on hand-held calculators. An example Thevenin exam problem is shown for reference in Figure 2. The discussion led to a change in the curriculum of the sophomore level courses. To enhance the preparation for their microelectronics course, the sophomores would now be required to solve several homework problems and a few quiz/exam problems symbolically. The problems were similar to that shown in Figure 2, but typically had simpler topologies. This curricular change led to another modest improvement in the initial microelectronics quiz and exam scores when compared to the previous year's scores. Again, this improvement is discussed in the results section.

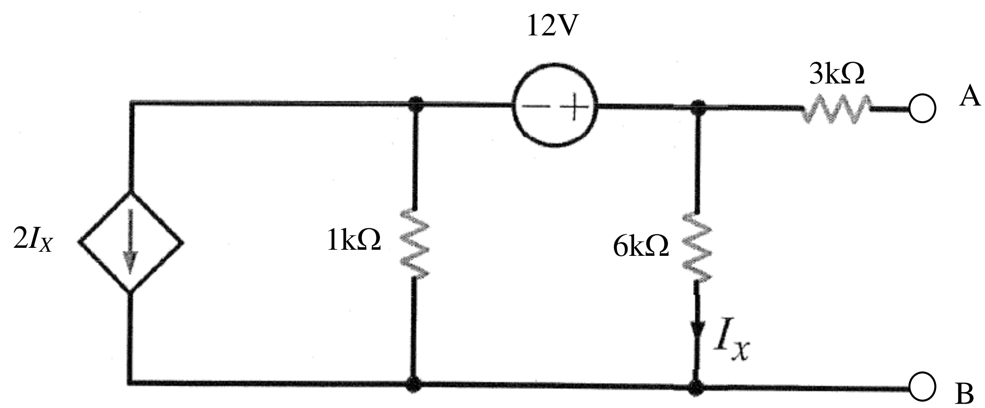

Figure 2: Example sophomore exam problem. Find Voc, Isc, and Rth.

The third feedback round brought significant changes to the sophomore linear circuits courses. In the original sequence of courses, the two courses had a total of approximately 12 laboratory experiments and one project. In the modified linear circuits sequence, there was a stronger emphasis on laboratory experience, project work, and open-ended design. There was also an increased use of pre- and post-lab simulation. In the second linear circuits course, an active learning model was also employed to improve learning by allowing students to practice more problem solving at their own pace[10,11]. The students met with their professors twice a week for 2 ½ hours for lecture, recitation, problem and/or laboratory work. The lectures were typically a brief introduction to theory followed by one or two example problems. The students used the remainder of the time to work on practice problems or perform measurements on example circuits. The students also met with their professors for 2 hours each week for laboratory or further recitation work.

The second semester required students to perform an increased amount of open-ended design. Here, only the first three weeks had prescribed laboratory experiments where each set of lab partners would solve the same problem. In the remaining weeks, students solved open-ended design problems for their laboratory experiments. Additionally, there were two open-ended design projects required during the spring semester course. The first project required students to design with a thermistor and the second project required students to design, build, and test a multi-band graphic equalizer.

One more significant change was made to the sophomore curriculum. The structural changes in the second semester allowed for more contact hours with the students. Much of this time was spent in recitation-style classes. This afforded the opportunity for repetition of first semester material. Feedback from the junior-level instructors showed the sophomore instructors that the juniors were week in solving Thevenin circuits similar to that shown in Figure 1. Researchers have shown Thevenin/Norton techniques to be perceived by faculty to be very important but on average to be only moderately understood by students[12]. Since Thevenin techniques were found to be a weakness in the juniors, the instructors chose to place more emphasis on this type of problem. Faculty reviewed literature that presented evidence that repetition is a significant factor in learning and knowledge retention. It is known that repetition of technical material produces both a quantitative increase in the amount that students learn and a qualitative change in students' processing strategies[13]. Therefore, changes were made in the sophomore-level second semester course to include two to three recitations focused on students solving symbolic Thevenin problems similar to, but in most cases more challenging than, the problem shown in Figure 1.

The combination of the structural changes, the increase in open-ended laboratory work, the increased emphasis on repetition, and the additional coverage of symbolic solutions of challenging Thevenin problems in the sophomore courses produced a significant increase in the junior-level student performance. Additionally, the course outcomes from the sophomore linear circuits sequence showed improvement. The most glaring improvement in the sophomore outcomes was in the s-domain circuit analysis. This improvement is linked directly to the increase symbolic problem solving employed in the coverage of both Thevenin circuits and s-domain circuits.

Results

A summary of the changes in the linear circuits courses and the microelectronics course is shown in Table 1. The resulting changes in quiz scores and initial exam scores for the microelectronics course is shown in Tables 2 and 3. The sophomore level course outcome measurements for the last two years of the study are shown in Figure 3.

Comparing the fall 2004 and 2005 microelectronics Exam 1 results, one can see improvement in the average, median, high, and low scores. The average and median improved by 6.0% and 6.5% respectively. Faculty attribute this improvement to the summer homework requirement at the beginning of the fall 2005 semester. The next continuous improvement method was to increase the emphasis on symbolic problem solving in the sophomore linear circuits course during the 2005-2006 academic year. This change required students to solve fairly simple topologies using symbolic solutions. The effect was seen in the entrance scores for fall 2006 microelectronics course. Here there was a 14.2% and 15.1% improvement in the average and median exam scores compared to the previous year. The quiz score average and median improved by 23.4% and 62.5% respectively. The final set of improvements came as a result of the changes in the 2006 - 2007 academic year linear circuits sequence. Here, there were significant changes made in the structure of the sophomore courses, the amount of repetition of material, and a large emphasis placed on challenging problems that required symbolic solutions. The exam scores, again, showed large improvements with the average and median increasing by 8.8% and 14.8%

respectively. The initial quiz, however, had a large decrease in the average and median scores. The scores retreated back to the 2005 levels. The faculty gave a second quiz to the students and improvement was demonstrated with a 13.7% increase in the average and no change in the median (the median was at the highest possible score for both years).

The outcomes for the linear circuits sequence were also measured and results for spring 2006 and spring 2007 are shown in Figure 3. Four of the five outcomes showed improvement while one of the outcomes showed a slight decrease. The notable result from these outcome measures was that the largest improvement was demonstrated in the s-domain analysis. Here, faculty attribute the gain to a large increase in the emphasis and repetition of symbolic problem solving.

Table 1: Summary of Changes in Linear Circuits and Microelectronics Courses

Course	Fall 2005 – Spring 2006	Fall 2006 – Spring 2007
Linear Circuits	Emphasis on Symbolic Problem Solving	Active Learning, More Repetition of Thevenin circuits, More Labs, Open-ended Design, Solving of Symbolic Microelectronics Thevenin Circuits
Microelectronics	Summer Homework Required	Summer Homework Required

Table 2a: Microelectronics Quiz 1

Microelectronics Quiz 1			
	Fall 2005	Fall 2006	Fall 2007
AVG	5.3684	6.625	5.6667
SDEV	3.6395	3.0134	3.2845
High	10	10	10
Low	0	2	2
Median	4	6.5	4
Count	19	32	12
Total Points	10	10	10

Table 2a: Microelectronics Quiz 1b

Microelectronics Quiz 1b			
	Fall 2005	Fall 2006	Fall 2007
AVG		8.2059	9.3333
SDEV		2.6717	1.7753
High		10	10
Low		1	4
Median		10	10
Count		34	12
Total Points		10	10

Table 3: Microelectronics Exam 1

Microelectronics Exam 1				
	Fall 2004	Fall 2005	Fall 2006	Fall 2007
AVG	24.81	26.434	30.197	32.856
SDEV	5.793	8.373	8.349	6.765
High	35	40	40	40
Low	13	14	11	19.5
Median	25	26.5	30.5	35
Count	21	19	33	13
Total Points	40	40	40	40

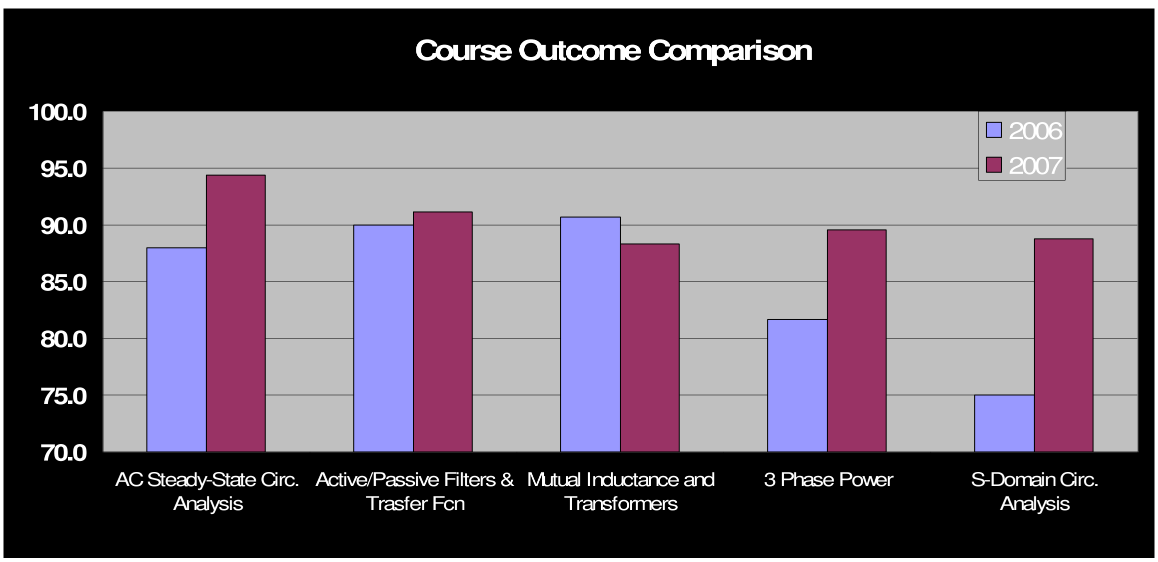

Figure 3: Sophomore Linear Circuits course outcome comparison for 2006 and 2007.

Discussion and Conclusion

This paper has demonstrated that a tight feedback loop between the sophomore level core electrical engineering courses and the entrance level measurement of the junior level microelectronics course results in dramatic improvement in the performance of microelectronics students. The feedback loop was implemented and results measured over a four year period with continuous improvement shown in each of the three years following the initial course modifications. The sophomore linear circuits course outcomes also demonstrated improvements between the final two years in the study. The most dramatic of these improvements was in s-domain analysis. This was attributed to the increased repetition and emphasis on symbolic problem solving throughout the sophomore year.

This author strongly recommends to the community of engineering educators that similar tightly coupled feedback loops be implemented across engineering programs. It is believed that continuous improvement similar to the improvement demonstrated in this paper can be made at institutions of any size – all it takes is communication between the instructors of the tightly coupled courses.

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