AC 2008-136: IN-CLASS CIRCUITS: USING PASSIVE COMPONENTS TO CREATE ACTIVE LEARNING

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Using Passive Components to Create Active Learning

Abstract

DC Electricity is the first math-based engineering technology course taken by all of our incoming engineering technology students. As such, it tends to be a course with high "drop-out" rates and also high failure rates for those that do complete it. Success in this course is paramount to a student's progress into subsequent electrical courses such as AC Electricity and Digital Electronics – both taken by all of our engineering technology students. Experience has shown that most students who drop DC Electricity the first time they take it, do not continue on in the engineering technology program, but change majors or drop out of college entirely. Therefore, fostering success in DC Electricity is critical.

After teaching the DC Electricity lecture course for two years with an average "drop" rate of 38%, and with only 55% of those students initially enrolled actually passing, the author decided that some changes were in order. Three changes were made to the DC lecture course, while the co-requisite DC lab course remained unaltered. First of all, homework was collected daily rather than weekly, in order to motivate students to keep up to date with the material. Secondly, an "attention" quiz was given at the end of each class period to encourage students to take good lecture notes, and as a means of immediate instructor feedback. Finally, and most significantly according to student surveys, the lecture was modified to include a daily "in-class" circuit, in which the entire classroom would take on the topology of one large circuit. The students were given component kits with long jumper wires, and would become part of the circuit that had just been analyzed on the board. Meters were passed around, measurements were taken, and results were compared with the theoretical calculations. Active learning was achieved.

After the trial run last spring, the results look promising. More than two-thirds of the class indicated that the in-class circuits significantly helped them to understand the circuit operation, and analysis techniques that were being discussed on a given day. The course drop rate was reduced to 7%, and the pass rate was increased to 73%.

The implementation and effects of these in-class circuits are the focus of this paper. The author will provide details regarding the contents of the students' component kits and will show detailed examples of circuits implemented in the classroom. Student survey results and course grading data will be used to examine the benefit of employing the in-class circuit as an active learning component of the passive circuit lecture.

Introduction

Nearly 50% of the engineering technology students taking our freshman DC Electricity course either drop or fail it. Few retake the course. Most who fail it change majors, and some drop out of college entirely. Although this attrition rate may be in line with engineering programs in general[1], in the spring of 2007, the author decided to make some improvements to the course - not by changing the content, but by changing the instructional methods used in the course.

Studies have shown that shifting course delivery from the passive lecture to a more learner-centered approach can have a significant impact on retention.[2] In light of these studies, three changes were made to the DC lecture course, while the co-requisite DC lab course remained unaltered.

First of all, homework was collected daily rather than weekly as had been done during the previous two course offerings. This was done in hopes of motivating the students to actively keep up to date with the material. In that regard, this change *may* have helped, but no improvement of homework scores was observed. It should also be noted that invoking this technique in the subsequent AC Electricity course had no impact on student retention.

Secondly, an "attention" quiz[3] was given at the end of each class period to encourage students to take good lecture notes which they could then use for the quiz. While the quiz was very beneficial to the instructor, in terms of getting immediate feedback and providing a review point for the next lecture, the student surveys suggest only about half of them found it helpful. The instructor has employed this method in various classes over the years but its inclusion has never made a noticeable difference in retention.

Finally, and most significant according to student surveys, the lecture was modified to include the active-learning element of a daily "in-class" circuit in which the entire class would assume the topology of one large circuit. Component kits with long jumper wires were "loaned" to the students who would construct (become) the circuit that had just been analyzed on the board. Meters were passed around, measurements were taken, and results were compared with the theoretical calculations. Active learning was achieved. The results look promising - more than two-thirds of the class indicated that the in-class circuits significantly helped them to understand the circuit operation and analysis techniques that were being discussed on a given day. It is in light of this positive student feedback regarding in-class circuits, that this paper has been written.

Details of this in-class circuit method are provided in the following sections. After a brief discussion of the need for active learning among technology students, the actual implementation of the in-class circuits is presented. The contents of the component kit, as well as a complete and detailed example of an actual circuit used in class are given. First year results are then considered by providing student survey and course grading data. Preliminary conclusions are provided in the final section.

Active Learning – Is it worth the effort?

Before examining the in-class circuit method of instruction, it is worthwhile to briefly review the concept of active learning. What is it, and does it work?

For the past ten years or so, conferences on education have been flooded by papers on active learning. When defining active learning, many of these publications settle upon variants of Bonwell and Eison's definition that active learning occurs through "instructional activities involving students in doing things and thinking about what they are doing".[4] While the lecture still maintains a dominant role in higher education many are now supplementing the lecture with various activities to create active learning experiences. It has been suggested that the most significant positive change that can be made to any given course is the addition of experiential (active) learning.[5] But is there any research that substantiates the benefit of active learning to the student?

Many studies have been done to assess the effectiveness of active learning, one of the most insightful works published being "Does Active Learning Work? A Review of the Research," by Michael Prince.[6] In this *Journal of Engineering Education* article, Dr. Prince examines what the research does and does not say about the effectiveness of active learning. He concludes that students remember significantly more lecture content when student focused activities are employed within the lecture. Albeit, similar results may be obtained by inserting 2-minute breaks into the lecture in which the students simply refocus their attention. Even so, it has been shown that focused learning activities can also significantly improve the student's ability to *understand* new concepts as well as *remember* them.

Although active learning has been shown to significantly benefit most students, it benefits certain "learning styles" more than others. Therefore the question should be asked, "What is the predominant learning style of the engineering technology student?" According to Broberg, when compared to engineering students, a significantly higher percentage of engineering technology students prefer an active learning style.[7] In learning style terms, an active learner is one who prefers to try things out rather than think things through. Therefore the more hands-on focus of the engineering technology program is a good fit for these students and the in-class circuit technique described in this paper provides yet another active learning experience.

Implementation of In-Class Circuits

Adding an in-class circuit to the lecture was a relatively painless experience. A circuit that was normally analyzed during the lecture was simply modified to use components provided in the kits, allowing it to be analyzed, built, and tested right in the classroom. A complete example is provided in this section.

The Parts Kit

Each student was given a simple parts kit containing the components shown in Table 1. Students were asked to bring the kit to each lecture.

Table 1. Parts kit contents		
Qnty	**Part**	**Comments**
1	9 volt battery	kept in a separate plastic bag
1	9 V battery clip	red and black wires, tinned ends
1	8 ft, 22AWG jumper wire (red)	stranded wire with insolated alligator clips on the ends
1	8 ft, 22AWG jumper wire (black)	stranded wire with insolated alligator clips on the ends
2	100 ohm, ½ W resistor	5% tolerance
2	1 k ohm, ½ W resistor	5% tolerance
1	Zipper-type bag	1 quart size with the zipper

The entire kit was packaged in a "zipper-type" plastic bag and given "on-loan" to the students for the entire semester. The 9 volt battery was packaged in a separate "baggie" to prevent shorts across the terminals, potentially creating dangerous heat in backpacks. (Recall that the goal of this project was to retain students!) The exceptionally long jumper wires allow for easy connection across aisles, as well as allowing for the measurement of wire resistance in one experiment. One-half watt resistors were chosen rather than one-quarter watt in order to better endure the stresses of backpack transportation. The complete kit is pictured in Figure 1.

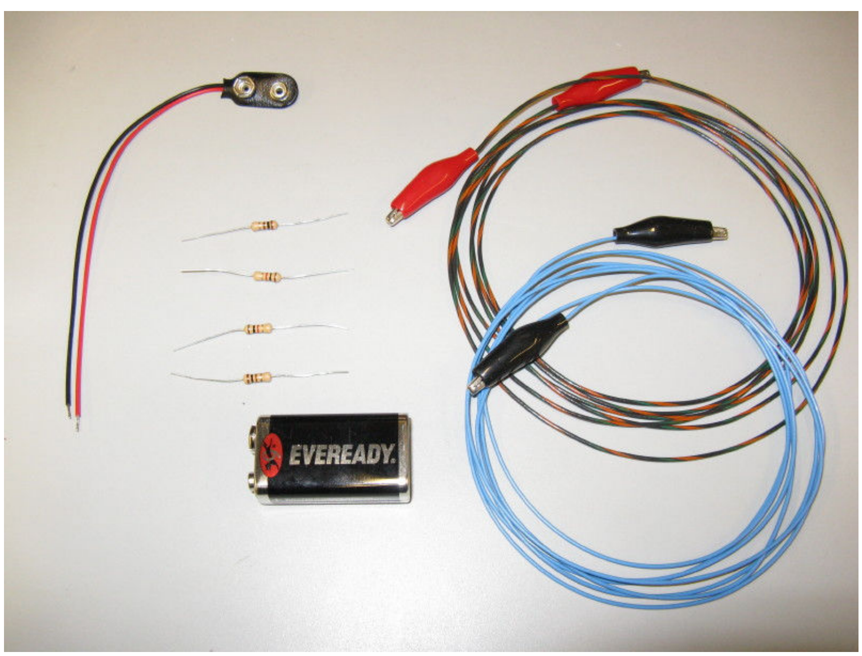

Figure 1. The parts kit

An Example In-Class Circuit Using Current Division

On day 11 of the course, the students were introduced to Kirchoff's current law, and the current divider formulas were developed. Toward the end of the lecture, the circuit of Figure 2 was drawn on the board, and the students were asked to calculate I_1 and I_2. They were encouraged to use both forms of the current divider formulas.

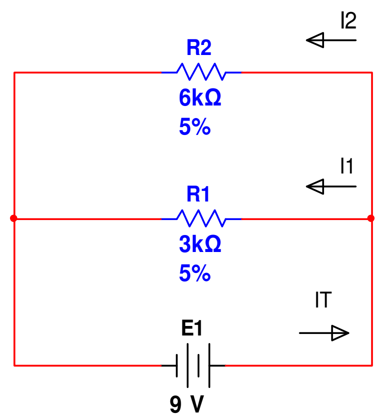

Figure 2. Current divider test circuit

The following calculations were performed:

$R_T = R_1 \parallel R_2 = 6\ k\Omega \parallel 3\ k\Omega = \mathbf{2\ k\Omega}$

$I_T = E_1/R_T = 9\ V / 2\ k\Omega = \mathbf{9\ mA}$

Using the first form of current divider:

$I_1 = I_T\ R_T / R_1 = (9\ mA)(2\ k\Omega) / 3\ k\Omega = \mathbf{6\ mA}$

Using the second form of current divider:

$I_2 = I_T\ R_1 / (R_1 + R_2) = (9\ mA)(3\ k\Omega) / (3\ k\Omega + 6\ k\Omega) = \mathbf{3\ mA}$

The instructor placed the solutions on the board. Then, using the overhead transparency shown in Figure 3 for guidance, the entire class created the circuit to be tested. Note that this classroom is arranged with 4 rows of tables with up to 6 students per half row. In this example there were no students in the front row.

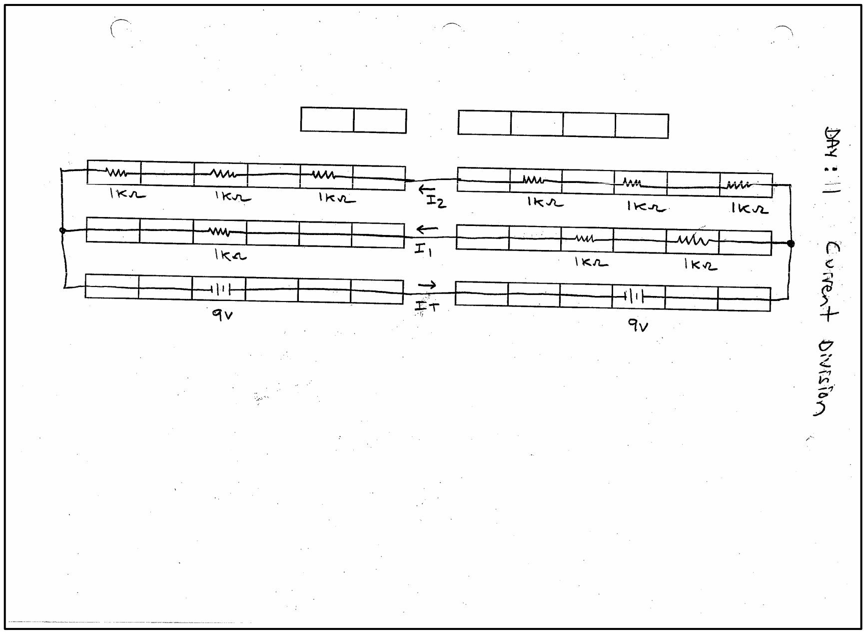

Figure 3. The in-class circuit transparency

The instructor provided a DVOM that was passed around the classroom to make the current measurements. I_T was measured, the result was recorded on the board, and the students were asked to explain any differences between the measured and calculated values. Suggestions such as "the battery voltages may not be 9 volts" were then verified with the meter. Likewise I_1 was measured and discussed. Finally, I_2 was measured, but before the actual measurement was made, the instructor asked the class to "predict" the value based on the condition that this circuit branch had twice the resistance of the previous branch. Yes, it did have exactly half the current!

Other In-Class Circuits

Most lectures in DC Electricity were enhanced by the inclusion of an in-class circuit based on one of the circuits that would have normally been analyzed during the lecture. A few of the more memorable circuits include the following:

- Conductor Resistance – All 40 students connected both 22 AWG 8 ft jumper wires in series and the total resistance was exactly the same as calculated - to a tenth of an ohm!
- Series Sources – All 40 students connected their 9 volt batteries in series creating a nearly 400 volt potential. The instructor then connected a 100 ohm resistor which immediately (to his surprise) burst into flames! A year later the students still talk about that experiment.
- The Unknown Resistor – In a circuit with known source and component values, a student inserted an "unknown" resistor. The class had to make V and I measurements at other points in the circuit to be able to identify the "mystery" resistance.
- The Open Circuit – With a single battery and a "chain" of 100 ohm resistors in series with each battery terminal, the students seemed to be amazed that the full battery voltage really does appear at the open terminals.

Time does not permit the mention of all the in-class circuits used during the semester, but almost every lecture was able to incorporate one. Figures 4 and 5 show students enthusiastically creating the in-class circuit.

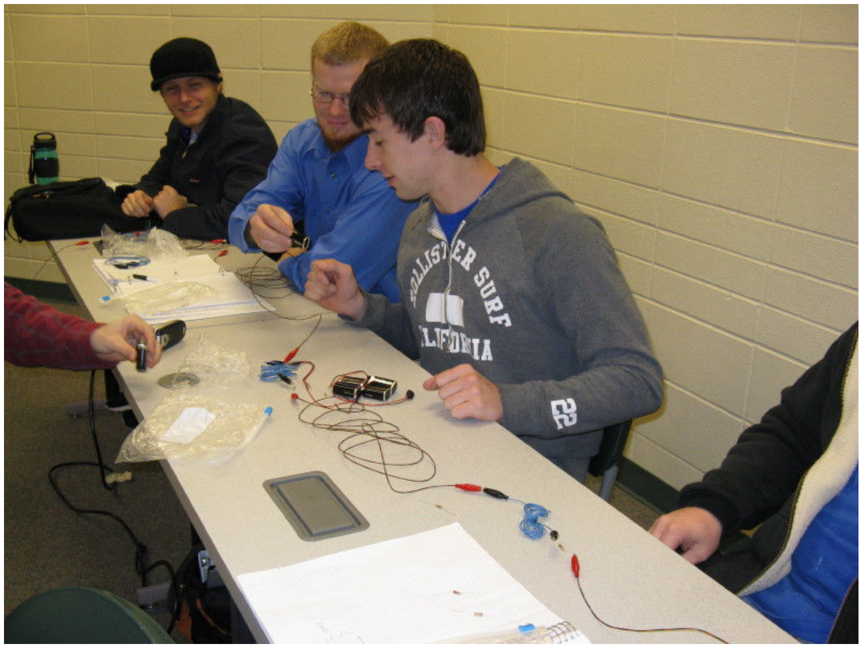

Figure 4. Enthusiastic students building the circuit

Figure 5. More enthusiastic students becoming “part” of the circuit

Implementation Hints

When implementing in-class circuits, ask questions. Asking good, thought-provoking questions is the key to fostering active learning during the in-class experiments. McKeacie has said that active learning occurs in experiences where the students are thinking about the subject matter.[8] The in-class circuit is a great way to consider and verify a host of "what if" type questions: "What if the voltage is doubled?"; "What if the resistance is halved?" The changes can be quickly implemented and the results observed.

When creating the circuits, vary the classroom circuit topology each day so that everyone gets to insert various components. Also, vary the student usage of the meter.

Results

The impact of the course changes implemented in the spring of 2007 appears to be significant. While the author cannot attribute the improvement to in-class circuits alone, the majority of students found them helpful as discussed below.

Course Results

The trial run of the in-class circuit approach occurred in the spring semester of 2007. The author had taught the same course from the same textbook during the two previous spring semesters. Student data provided in Table 2 shows that significant improvement occurred during the first year of using in-class circuits. The most significant change was observed in the percentage of students dropping the course which went from 36% and 39% the previous two years, down to 7%. Of the students initially enrolled in the course, 73% passed compared to 56% and 55% the previous two years.

Table 2. Course Results

Semester Taught	Spring 05	Spring 06	Spring 07
Number of students beginning the course	25	33	41
Number of students dropping the course	9 (36%)	13 (39%)	3 (7%)
Number of students passing the course	14 (56%)	18 (55%)	30 (73%)
Number of students with "C" or better	11 (44%)	13 (39%)	24 (59%)

In-class survey Spring 2007

Eight weeks into the course, students were given a survey to determine how well various course activities were contributing to the learning of DC circuit analysis. The contributions were given a score of 0 to 4 using the scale shown in Table 3. The survey was taken by 28 students and the results are summarized in Table 4.

From the survey data it can be seen that students found the lecture to be the most helpful part of the course. Second in importance to the students were the tests given – which was actually a bit of a surprise. This was followed by the in-class circuits which the students ranked as slightly more helpful than the homework. Not obvious from the results provided is the fact that only 2 of the 28 students indicated that the in-class circuits were not helpful in learning the material.

Table 3. Scoring System	
4	Very helpful
3	Helpful
2	Neutral
1	Not very helpful
0	Not helpful at all

Table 4. Student Survey Results			
	Number of Responses	Average Score	Number of Responses > 2
Lecture	28	3.39	27 (96%)
Homework	28	2.93	18 (64%)
Tests	28	3.14	21 (75%)
In-Class Experiments	28	3.00	19 (68%)
End-of-Class Problems	28	2.64	15 (54%)

The survey also provided students opportunity to provide written comments to support their rating. Comments from students indicating that in-class circuits were helpful, were as follows:

- It gave me a realistic idea of what a circuit looks like.
- I wish we did more of these.
- Excellent.
- They are fun and wake people up.
- More of a hands-on thing, so helpful for people that like lab.
- Fun.
- We need to blow more stuff up; more destruction to resistors and batteries.
- Very helpful in visualizing a circuit.
- More of them with a little more depth and hands on for me.
- It's fun to prove theory.
- Maybe divide the class into small groups and make measurements.
- Fun and also an experience to know what to do and not to do.

Comments from students indicating that in-class circuits were not helpful were:

- I don't need to actually see something work to understand how it does work, but I can understand that some people might.
- For the amount of time spent I don't get much out of them.

<u>Course Evaluations</u>

Toward the end of each semester university-issued course evaluations are completed by the students. In the spring of 2007, almost every area of the DC Electricity course evaluations improved, but the area that really stands out is "Enthusiasm (instructor) when teaching," which increased from a 2-year average of 3.7 to a new high of 4.5 (on a 5 point scale). Overall the course evaluation improved from 4.2 to 4.5.

Conclusions

Nearly 50% of the engineering technology students taking our freshman DC Electricity class were either dropping or failing the course. The first year after the insertion of in-class circuits into the course, that rate dropped significantly to about 30%. Was the improvement due solely to the in-class circuits? Probably not, but the student surveys indicate that the in-class circuits were a very positive addition to the course. Was course content sacrificed? No. No topics were eliminated. The implementation seldom took more than 5 minutes of class time. Was it expensive? No. The component kits can be put together for about $3.00, and can be reused the next semester. While some have advocated the beneficial integration of lecture into the laboratory[9], the advantage of this approach is that it can be implemented in any classroom, with any number of students. Does active learning really take place? Probably. If nothing else, the in-class circuit provides a beneficial break in the lecture flow,[10] and creates more interaction between the professor and the students. Was it worth the effort? Definitely. The first year data suggests that 12 more students passed DC Electricity this time, than would have under the format of the previous two offerings. Even if only one more student succeeds each time because of the in-class circuits, it is worth the effort to this professor.

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