Peer-Led Team Learning: Adjunct to Lectures in an Electrical Engineering Course for Non-Majors

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Abstract— Peer-Led Team Learning (PLTL) is a recognized model for teaching and learning in which select students in a course return in later semesters to serve as peer leaders who facilitate small learning groups. At our institution (a small, private, research-intensive university), this technique is adopted in Workshops; our peer leaders meet weekly with small groups of students to guide them through sets of exercises designed by the instructor(s) of the course. Peer leaders receive instruction and support in pedagogy and group dynamics in a course jointly taught by a learning specialist from the Center for Excellence in Teaching and Learning (CETL) and the instructor of the course. Workshops have been adopted in many courses, ranging from Chemistry, Biology, Earth Sciences, Physics, and Optics, to Economics and Business. This paper describes the use of Workshops for several years in an Electrical and Computer Engineering (ECE) course intended for non-ECE majors.

We discuss the processes and pitfalls for initiating the use of Workshops in this and other courses, present an example of Workshop problems and questions currently in use, and discuss the value of the Workshops to students, peer leaders, and faculty as told to us in surveys, course journals, and reflective sessions held after the course.

Keywords—Peer-Led Team-Learning, collaborative learning, circuits, non-majors.

I. Introduction

Students majoring in mechanical engineering and optics are typically required to complete at least one course on circuits, often without an explanation of the importance of this course. At some institutions like our own, they are then told that they can satisfy this requirement by taking an electrical circuits course designed for those who are not electrical and computer engineering (ECE) majors. Therefore, a significant fraction of students enter the course not knowing why it is required or what good it can possibly do them. Even worse, many already know they hate circuits (they have seen them in high school and in physics, after all, and seldom fully understood them there), and they wish they could be taking a course more relevant to their real interests. Too often, the response to this dilemma is an overreliance on the instructor's capacity to be profoundly inspirational and personally engaging as s/he works through the necessarily esoteric mathematics on the board in front of the class.

We began with the premise that there must be a better way to engage and motivate students in this service course. We had several requirements in mind: (1) we wanted to employ an approach that introduces students to the discussion format typical to research groups, (2) we wanted to engage the students for longer periods than a short lecture class can accommodate, (3) we sought to use methods proven in other contexts, and (4) we wished to provide immediate and active feedback and direction so the students use their time most efficiently. From the start the goal was not just to improve grades, as this is more an "enrichment" course than a "core" course for the major. As will be seen, we did find a positive correlation between grades and participation in the intervention.

II. Workshops

Our small, private, research-intensive university was one of the original development sites for the Workshop, or Peer-Led Team Learning, a recognized model for teaching and learning[1-6]. The initial implementation here was in organic chemistry[7]; subsequently, it has been adapted at our institution to many other courses, ranging from biology, earth sciences, optics, and physics to business and nursing.

Workshops at our university meet once a week outside of regular lecture hours for two-hour sessions. All students in the course are members of a Workshop; these groups of five to twelve students meet with their Workshop Leaders, who distribute the problem(s) of the day and guide the students in their analysis and discussion of each problem and the issues it raises. (An example problem is given in Appendix A of this paper.) Often the problems are worked on in subgroups and then presented to the larger group. Other times, one student serves as a scribe at the board while the rest of the group offers suggestions on how to proceed. The key is to engage as many students as possible in generating solutions and discussions. Another goal for the Workshop is efficiency; unlike lectures, during which students typically take notes to facilitate their study of that day's concepts at some later point, the Workshop is designed to promote on-the-spot learning of the material, with guidance from an experienced learner. The Workshop Leaders are paid a small stipend for this part of their activities, and they receive course credit toward graduation for the leader training course.

Workshop Leaders are undergraduate students who have done well in the course and return in later semesters to serve as

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peer leaders to facilitate small learning groups. These peer leaders direct small groups of students through sets of exercises designed by the instructor(s) of the course[8,9]. Workshop Leaders receive instruction in pedagogy and group activities in a separate course, originally designed by the second author[10]. This course is jointly taught by a learning specialist from the Center for Excellence in Teaching and Learning (CETL) and the instructor of the parent course.

Formatted as a two-credit course, the leader training program is designed to prepare Workshop Leaders for their role as facilitators. Each of the 90 minute weekly class periods is equally divided between a discussion of teaching and learning strategies and a review of the material for the upcoming Workshop sessions[8]. The pedagogical portion of the session covers a variety of issues over the semester, e.g., techniques for facilitating group discussions[11], question-asking strategies[6], and student development theory[12,13]. It also provides a venue for leaders to talk through any problems encountered during their recent sessions with their own students. In the content review portion of each class session, the instructor of the parent course rehearses the pertinent material with the leaders for their upcoming Workshop sessions and also points out the higher level ideas and concepts to be illustrated. (See the "Notes given to the Leaders" in Appendix B for an example of the details Leaders are provided about Workshop problems.) The leaders write journal entries each week about their experiences and also carry out a project to investigate a related topic of interest to them; they have created projects like "Increasing Involvement of Women in Engineering" or "How do Students at this University Perceive Engineering: Results of a Survey." The last few meetings of the semester are devoted to poster presentations by the leaders, a simulation of the usual entry-level presentation at scientific conferences.

In the Workshop sessions themselves, it is important that the material and techniques or reasoning processes provided to the students are reflected in whatever assessment tools are used in the course, whether they are exams, papers, or portfolios. If the material from the Workshops is seen as separate from the course, or disconnected from assessment, then it will not be taken seriously, and students understandably will not believe they should participate.

The design of the Workshop program is intended to mimic the organization of a university research group, in which an experienced director works with less experienced people to guide them in finding interesting questions to ask, figuring out how to collect information and evidence to address those questions, and formulating appropriate answers. An important point is that those activities are usually not carried out in isolation, but as part of a group, and that the answers are not known in advance but must be worked out. The Workshop program applies the same model to learning a subject (for the students) and learning about teaching (for the leaders).

Over many years and many courses in diverse areas, we have found that Workshop groups of six to eight students with one Leader generally work best. This is small enough to allow personal interaction with the Leader, but has possibilities for multiple subgroups (pairs or trios) to be formed to work on problems. This target Workshop size then determines how many Leaders are needed for a particular course. The course described here has ranged in size from 100 students (we arranged for 12 Workshop sessions by having some of the eight Leaders conduct two sessions per week) down to about 50 students (we had 6 Leaders that semester.)

III. ASSESSMENT

To examine the effect of this model on student performance, the second author and others[14] have compared course sections across time, i.e., examining student performance data in semesters prior to the implementation of Workshops and after the inclusion of this model. Other studies have included two sections of the course, both with a large number of students, taught by the same instructor, covering the same material, and with Workshops implemented in one section and not in the other. The same assessment tools and opinion questionnaires are used in both sections, and the grades and survey answers are compared. Studies on Workshops performed in this way typically have demonstrated the positive impact of Workshops on student performance[3,10,15,16]. Our opportunities for a comparison study were precluded for this particular course, as when the Workshop model was first taken up the instructor had not taught the course many times and the content was still changing. The instructor was able to offer only one section, the students could not have accommodated separate courses within their schedules, and the number of students in each section would have been too small to allow definitive conclusions to be drawn.

Instead, we began offering Workshops to all the students in this course. In the initial two years attendance was optional, and in subsequent years we began counting Workshop attendance as a part, usually 10%, of the course grade. We allow each student to miss two Workshop sessions with no penalty, then begin removing points, essentially 1% per Workshop missed. In addition to usual assessment practices (homework problems, laboratory participation, and examinations), we also administer surveys to the students to collect their reactions to the course, including Workshops.

We consciously strive to make the problems used in the Workshop sessions illustrate concepts and techniques that will be included in the assessments and have found that designing Workshop sessions to prepare for laboratory sessions are especially appreciated and useful. In addition, the Workshop Leaders point out both real-life examples and situations in later classes that rely on the concepts and techniques being covered.

IV. OUTCOMES

The reaction of students to the Workshops is understandably mixed. There are students who, rightly or wrongly, believe they learn well on their own, or have had a fairly strong background in electrical circuits in high school; they at least initially may be harder to engage in this format. Others may have formed informal study groups on their own, or have other coping mechanisms in place. These students usually know a good thing when they see it, and make use of the Workshops to reinforce their learning; they also know the adage that you never learn something as well as when you teach it. They often become informal "assistant leaders" and help others in the Workshop who are having problems understanding the material, knowing that they may need help on the next section of material. They do everything that is expected of them and do it well, and often become Workshop Leaders themselves in subsequent semesters.

There is another group of students who probably would pass the course but may not grasp the material well enough to apply the ideas and techniques to new situations. This is one of the groups we are most trying to reach through Workshops. By having them work with the concepts and materials of the course at a deeper level than usual homework problems, we believe we help the material come alive for them.

These groups above typically make up a large fraction of the students enrolled in this course. They are in their third or fourth year of a demanding and rigorous program, and most students without the mathematical or engineering background to succeed in the course typically have already decided to leave engineering.

Then there is the group of students (usually a very small number) who will struggle with the material or will believe throughout the course that they are "doing OK" when, in reality, they are failing. Through Workshops, we hope to help these students resolve any conceptual difficulties so they can succeed in the course.

An important observation is that most students vote with their feet and go to Workshops regularly, as can be seen in Figure 1, in contrast to the thin and sporadic attendance typical of standard recitations when not required.

More information about the impact of Workshops on students can be found in our student surveys. These surveys are anonymous, so we cannot correlate comments made by students with their performance; instead, we review these comments individually.

In general, we receive encouraging comments:

Workshop was AWESOME!! The best experience in a workshop ever!

Workshops and labs are well integrated.

Workshops were excellent in supporting material.

In response to the question "What are the major strengths of this [overall] course?" students often reply with comments that refer to Workshops:

Workshops. Fair tests and grading.

Workshops

Workshops are good.

Workshops were the one good thing about this class.

Workshop!!! In class demonstrations.

Workshop. Labs were decent.

Labs and workshops were very helpful w/understanding of material.

In response to another question "What are the major weaknesses of this course?" we sometimes hear about the length of the Workshop sessions:

Workshops do not need to be 2 hours long.

We collected data for five years and were able to correlate final course grade with Workshop attendance, and found a positive, although small, correlation (see Figure 1). Over these years, we sometimes did not give credit for Workshop attendance and some years we did, so the portion of the grade for attendance has been removed and the grade re-scaled for the graph.

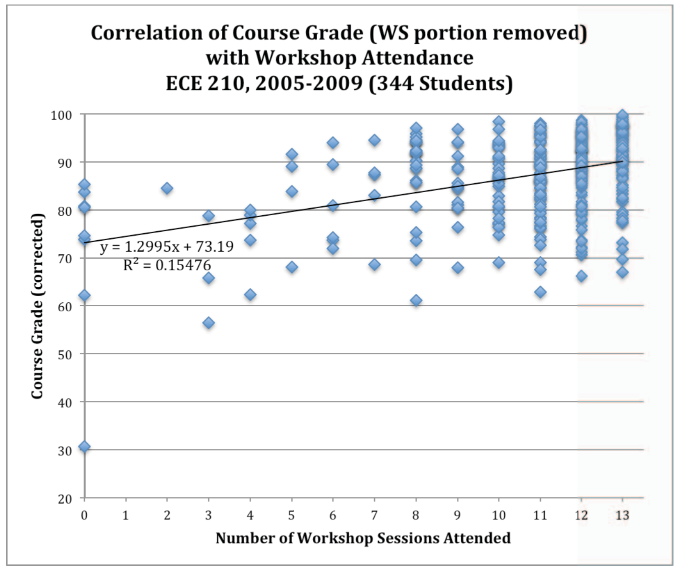

Figure 1 – Correlation of Course Grade (Workshop contribution removed) with the number of Workshop sessions attended for 344 students between 2005 and 2009. As can be appreciated from the low value of R^2=0.15476, the correlation is not very strong. As noted in the text, most students both attend a substantial number of Workshop sessions and ultimately do well in the course, so large changes or very high correlations were not expected. The Workshops provide an alternative learning environment that some students find very useful.

V. DIFFICULTIES ENCOUNTERED

Like any change to the status quo, there can be difficulties with implementation of Workshops. One we found is that it requires the instructor to begin preparing for the course during the previous semester. Workshop Leaders must be recruited and selected, preferably about the time students register for classes for the next semester, which at our institution happens about halfway through the current semester. While Chemistry and other departments often have an excess of applicants for Workshop Leader positions, leading to competitive hiring practices and extensive interviewing, within Engineering there tends to be a smaller applicant pool, resulting in less selectivity in hiring and larger than optimum Workshop groups. This may be due to the fact that upper-class engineering majors tend to be very busy with internships, design projects, etc.

Another difficulty is that instructors must develop their own set of Workshop problems for each course, and they often need to be modified and updated from year to year. This is best done by the instructor, with input from the Workshop Leaders, so that the class work remains in synch, uses the same terminology as the Workshop problems, and includes the topics in Workshops in lectures and assessments. The time for this development is, of course, largest in the first year of adoption.

VI. (UN)INTENDED CONSEQUENCES

We anticipated that some students would benefit from Workshops and the additional teaching style and structured time with the material, that Workshop Leaders would benefit somewhat from the review of the material in a course they had already taken, and that the leadership and teaching opportunities would be fruitful. One thing we did not anticipate is that virtually every leader who has subsequently gone on an interview, either for a job or a professional school admission, has reported back that the interviewers were both intrigued and impressed by the Workshop program, and that most of their interview time was often spent describing and reflecting on their Workshop Leader experience. Having been a Workshop Leader is now recognized as a useful experience.

VII. CONCLUSIONS

The high attendance in Workshops, the modest increase in student performance that correlates with Workshop attendance, and the expressions of satisfaction by students, student leaders, and instructors is sufficient to motivate those who have adopted this model to continue its implementation.

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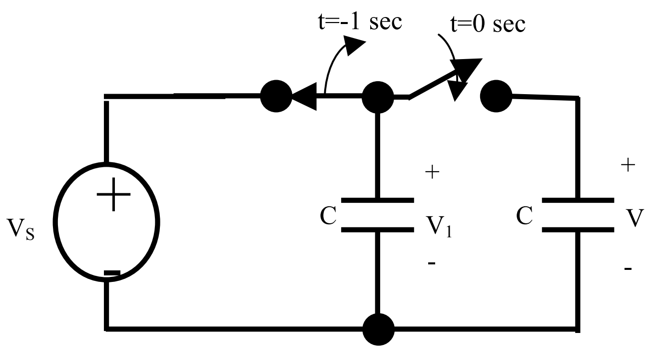
VIII. Appendix A: Example Workshop Problem (given to students)

Consider the circuit shown below, which contains two identical capacitors:



The capacitor on the right is initially discharged (V_2=0), and the one on the left is charged to a voltage V_S. The switch on the left is opened at t=-1 sec, and the switch on the right closes at t=0 sec.

A.

What energy is stored in the capacitor on the left between t=-1 and t=0 sec?

B.

What is the voltage on the two capacitors a long time after the switch on the right closes (say at t=10 sec.)? (HINT: Consider conservation of charge q.)

C.

What energy is stored in the two capacitors at t=10 sec (individually and the total)?

D.

Compare the energy in parts A and C. What happened to the extra energy?

E.

Let's figure it out. First, allow there to be a resistor in the "top" wire connecting the two capacitors:

Will the presence of the resistor change any of the Initial and Final Conditions you found above?

F.

What is the time constant of the circuit for the time regime AFTER the second switch has closed?

G.

Derive an expression for the voltage across the resistor for the time regime AFTER the second switch has closed.

H.

Write an expression for the POWER, p(t), dissipated in the resistor for the same time regime.

I.

Integrate the POWER from t=0 to ∞ to find the total ENERGY dissipated in the resistor. How does it compare to the values you found in Part D? Does it depend on the value of the resistor?

Appendix B: Notes given to Leaders in Review Session

Some students have asked for a more complete explanation of the "charged capacitors" problem. Here are points to consider: When charged, the left capacitor has a charge q of q=CV_s, and a long time after the switches are thrown that same charge is evenly distributed across the two capacitors (by symmetry if nothing else, why would one of two identical capacitors have more charge on it than another? Also, they have the same voltage across them, so they must have the same charge on each.) So, $q=q_1+q_2$ and $q_1=q_2$, so $q_1=q/2$, and $V_1(\infty)=V_2(\infty)=V_s/2$. The total energy stored in the left capacitor at t=0 was $W(0)=(CV_s^2)/2$, and the total stored at t=∞ is

$$W_1(\infty)+W_2(\infty)=\frac{1}{2}CV_1^2+\frac{1}{2}CV_2^2=C\left(\frac{V_S}{2}\right)^2=\frac{1}{2}\left(\frac{1}{2}CV_S^2\right)$$

or one half the original energy.

To see where the "extra" energy went, allow there to be a resistance R to the wire in the top of the circuit. Now we have two capacitors in series and a resistor in between, so the effective capacitance C_{eq} is $C_{eq}=\frac{CC}{C+C}=\frac{C}{2}$, and the time constant for the circuit will be $\tau=RC_{eq}=\frac{1}{2}RC$. We can now find the power dissipated in the resistor, P_R, and integrate over all time from t=0 to t=∞ to find the total energy dissipated, W_{dis}.

$$P_R(t)=I^2(t)R$$

$$I(t)=\left[I(0)-I(\infty)\right]e^{-\frac{t}{\tau}}+I(\infty)=\left[\frac{V_S}{R}-0\right]e^{-\frac{t}{\tau}}+0$$

$$P_R(t)=\frac{V_S^2}{R^2}e^{-2\frac{t}{\tau}}R=\frac{V_S^2}{R}e^{-2\frac{t}{\tau}}$$

Integrate over all time to get

$$W_{dis}=\int_0^\infty\frac{V_S^2}{R}e^{-2\frac{t}{\tau}}dt=\frac{V_S^2}{R}\left(\frac{1}{-2\frac{1}{\tau}}\right)e^{-2\frac{t}{\tau}}\Bigg|_0^\infty=\frac{V_S^2\tau}{2R}=\frac{V_S^2RC}{2R(2)}=\frac{1}{2}\left(\frac{1}{2}CV^2\right)$$

NOTE: The amount of energy dissipated is INDEPENDENT of R, so half the initial energy is dissipated in the wire, no matter what the resistance is!

The question sometimes arises "What if we made this out of superconductors, which we all know have truly zero resistance? How would that circuit dissipate the extra energy?" The answer is that superconductors have their limits as well, one of which is a "critical current density" specific to the particular material serving as the superconductor. When the critical current density is exceeded the superconductor "goes normal" and becomes a normal conductor again. If we built this circuit of superconductors and put the whole thing in a liquid helium bath and then tried to do the experiment, we would find that the instant the second switch closed the (infinite) current would exceed the critical current density and the wire would become normal. The necessary amount of energy would be dissipated, then the current density would drop to zero and the wires would return to being superconductors again. The only thing one would notice is that a little extra helium would boil off due to the resistive heating, and everything would return to its regular condition.

We can even figure out how much helium would boil: Assume V_1=50V and C=1μF, for starters. The energy dissipated is then going to be 625 μJ, which, given that the heat of vaporization of helium is 0.0845 kJ/mol, means that only 7.4 μmol, or 166μliter, of helium will boil away due to the dissipated energy, probably not enough to notice.