
AC 2011-1176: USING ACTIVE LEARNING IN TEACHING ELECTRO-MAGNETICS

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Using Active Learning in Teaching Electromagnetics

Introduction

*“Learning is not a spectator sport. Students do not learn much just by sitting in classes listening to teachers, memorizing pre-packaged assignments, and spitting out answers. They must talk about what they are learning, write about it, relate it to past experiences and apply it to their daily lives. They must make what they learn part of themselves.”*¹

Active Learning (AL) is the process of engaging students in activities that require them to reflect on ideas and how they are using those ideas. Research in a variety of disciplines has identified the effectiveness of active learning approaches in learner retention of content, improved students’ attitudes and increased student achievement. Active Learning use in teaching and its research-based outcomes are presented in this paper.

The Electromagnetics course at South Dakota State University is a four-credit junior-level core course. It includes the toughest and most abstract topics and is taught once a year in the Spring semester. AL is used in teaching Electromagnetics to help students understand, visualize, and retain these topics. Engaging and motivating students is accomplished through the use of an interactive visualization software tool, use of the Students Response System (clickers), use of a tablet PC, solving problems and leading discussions in the classroom, and other AL approaches as presented below.

The readiness of the students, challenges, and success of these approaches are identified through comments on the student assessment survey tool, and the results of the Electromagnetics part of the FE exam. The results of the FE exam are a good measure of the extent of success of the use of these AL approaches since students graduating from SDSU are required to take the FE exam in their senior year as part of their graduation requirements. In addition, tips from personal experience and best practices on implementing AL in teaching Electromagnetics are also presented.

Definition of Active Learning

AL is generally defined as the use of *“instructional activities involving students in doing things and thinking about what they are doing”*². The focus of AL is on student learning rather than faculty teaching³. The responsibility for learning is the student’s who actively engages with the content and is cognitively active in the learning process. AL is an approach to teaching and learning which enlists strategies including but not limited to: reading, writing, discussing, problem-solving, analyzing, synthesizing, and evaluating.

A related concept to AL is that of student-centered teaching and learning, an instructional approach in which students influence the content, activities, materials and pace of learning^{4, 5}. Other related terms include collaborative learning, cooperative learning, and problem-based learning.

Motivation for Active Learning

The current generation of college-age students is sometimes referred to as primarily active learners⁶. *“Students learn more when they are intensely involved in their education ... when*

*students collaborate with others in solving problems or mastering difficult material, they acquire valuable skills that prepare them to deal with the messy, unscripted problems they will encounter daily during and after college”*⁷. Research in a variety of disciplines has identified the effectiveness of active learning approaches in increased learner retention of content⁸, improved student attitudes and performance⁹, and improvements in writing and thinking skills²

In addition, according to the Learning Pyramid¹⁰, after a two-week period, learners tend to remember only 50% of what they read, hear, and/or see while they retain up to 90% of what they learn when they were actively engaged by doing or saying. So, active experiences tend to help content retention more than passive ones.

In addition, technology applications and access enable a “*variety of discipline-specific pedagogical strategies that require students' active engagement and that develop their problem-solving and problem-posing skills in the context of technology-enabled learning environments*”¹¹. The use of technology based innovative pedagogies for the classroom teaching can offer faculty the opportunity to reach the new generation of learners¹²

In conclusion, to foster higher level of cognitive and affective learning, teaching methods which encourage student engagement and involvement are preferable to more passive methods.

Active Learning approaches used in the classroom

After teaching the Electromagnetics course for many years using conventional methods, it was obvious that students had great difficulty understanding and grasping the material which resulted in bad students' attitudes towards the course. It was then decided to use AL approaches to teach this course to enable an active teaching-learning environment, promote student centered learning, help students visualize the highly abstract topics in this course, and secure sustainable IT resources to support teaching and learning activities.

While lecturing is still the method of choice for delivering information and course content to students, a variety of AL activities are used to prevent predictability and to increase impact. AL approaches are chosen to be relevant to the Electromagnetics course content, to provide practice with key concepts, and to contribute to student learning. Such activities have included the following:

- Give mini-lectures using power point presentations not to exceed ten to fifteen minutes at a time bracketed with brief two to five minutes active learning experiences.
- Pause to give students a chance to ask questions or clarify their notes with others.
- Provide a problem for students to solve while in class; students can get help from professor or students colleagues and report their solutions.
- Involve students in evaluating their learning by using student response systems (clickers) to ensure understanding of key issues and identify areas of concern.
- Engage students in peer-teaching through an activity called Think-Pair-Share; students think about a question, answer using the clickers, engage in discussion with a colleague or two, then answer the clicker question a second time.

- Incorporate the use of multimedia software, CAEME (Computer Applications in Electromagnetics Education) ¹³, to help students visualize the abstract concepts in the course such as wave propagation, reflection, transmission line matching, and others.
- Display a virtual laboratory experiment to demonstrate an idea or a physical phenomenon. This is frequently done using the CAEME simulation software package.
- Show in-class videos to introduce basic concepts in addition to historical facts about their discoveries.

Results of using Active Learning in teaching Electromagnetics

Students at the junior level had never been taught in any of their lower level courses using AL approach. While they initially resisted these approaches and had negative attitude towards them, their understanding and retention of the material as shown by their FE exam results showed significant improvements. With time, the course gained good reputation among cohorts of students due to enhanced attitude towards the material covered by the course.

Initial negative comments on students' evaluations, the IDEA (Individual Development and Educational Assessment) survey tool, were actually the sought-after results of the teaching methods used. For example, using AL most learning occurs through "*students teaching other students*" ⁸, students commented against this type of learning: "*..she (instructor) makes other students in the class teach each other*". They also commented negatively on the process: "*... don't like the active learning thing*".

Students also wrote comments that the author took as fruits of the AL process while administrators took them as failure of the professor responsibilities. Examples of such comments included: "*I did not feel like I was taught anything from the instructor, we kind of had to learn it ourselves through active learning.*"

With the professor's persistence and experience, students started to appreciate the use of AL approaches. Comments included: "*Group work was helpful,*" "*.. it (group work) allowed me to understand the material better,*" "*the extra stuff (videos) helped bring purpose and history to the material,*" "*I like the visuals to teach the material. I also like doing problems in class and getting immediate feedback,*" "*working in groups on examples was very helpful. The videos and software was also helpful in clarifying the material,*" "*The software and videos helped to visualize the concepts in the course,*" and "*...it helped it stick to my mind,*" "*.. it (AL) kept class interesting.*"

Meanwhile, to verify the positive results of using AL in teaching the Electromagnetics course, results of the Electromagnetics afternoon part of the FE exam required from all our seniors were compiled. Table 1 shows the percentage of correct answers by SDSU students, and the same nationally for six semesters prior to using the AL approaches while Table 2 shows the same results for six semesters after. These tables also show the average percentages of correct answers for each of the six semesters. These results show that the average percentage of correct answers by SDSU students before the use of AL (46.33%) is lower than the national average percentage (50.17%) by 3.84 %. While after the use of AL, the average percentage of correct answers by SDSU students (56.33%) is higher than the national average percentage (49.83%) by 6.5 %. This proves more understanding of the complex topics and higher retention of the material covered using AL approaches.

Table 1. Results of the Electromagnetics Part of the FE Exam Prior to Using AL

	# Students	# Questions	SDSU % Correct	National % Correct
Spring 02	21	6	46	50
Fall 02	10	6	42	46
Spring 03	13	6	46	50
Fall 03	5	6	60	66
Spring 04	16	6	44	44
Fall 04	12	6	40	45
Average			46.33	50.17

Table 2. Results of the Electromagnetics Part of the FE After Using AL

	# Students	# Questions	SDSU % Correct	National % Correct
Spring 05	10	6	45	42
Fall 05	7	4	61	47
Spring 06	14	4	45	46
Fall 06	3	4	75	63
Spring 07	12	4	62	56
Fall 07	11	4	50	45
Average			56.33	49.83

Tips for incorporating Active Learning approaches

In implementing Active Learning approaches, the following suggestions might prove useful¹⁴:

- Explain to students the benefits of Active Learning and the reason for using such an approach in the first day of class; share with them a paper to read or some references to go back to.

- Take it slow by introducing one learning activity at a time.
- Interact with students during activities and stay engaged.
- Debrief students on the activity used and the learning outcomes served.
- Evaluate and track the effectiveness of activities used throughout the semester.
- Keep only the activities that worked well for you and the students.

Conclusion

The Electromagnetics course at SDSU was a good candidate to be taught using AL approaches starting Spring 2005 due to its highly abstract and complex topics. At first, students not used to be engaged and taking responsibility of their own learning wrote comments showing their misunderstanding of the whole process and described their concerns.

However, students' understanding and content retention were enhanced as proven through their own comments in subsequent years, and the compiled results of the Electromagnetics part of the FE exams. Furthermore, actively engaging students in their learning through using AL approaches has improved students' attitudes towards the Electromagnetics subject which is fundamental to all areas of Electrical Engineering.

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