The Art of Creating an Active Learning Environment

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Abstract

Active learning is truly the key to education. To paraphrase Piaget, …in order for a student to understand something she must construct it herself, she must re-invent it. As an award-winning teacher, I have been involved in engineering education for roughly 15 years. During my tenure, I have seen and employed many teaching methods and philosophies. One observation that seems to be constant though it all is that students who are engaged in the learning process master the material. Students who are not engaged generally do not succeed. The best way to engage students is to create an exciting active learning environment.

Life for students today is different than it was twenty years ago. Today there are many concurrent distractions competing for their attention. Television, cell phones, relationships, Internet, and world events impact them simultaneously. To compete with this constant barrage of information and distraction, we need to create a learning environment that speaks to students where they are and how they are listening. One-dimensional, lecture classes have a very hard time competing for the attention of today's student. A multidimensional approach is called for. One that addresses diverse learning styles and encourages student engagement through the artful creation of a stimulating learning environment.

This paper describes the theory behind active learning, the art of creating an active learning environment, and successful examples of active learning thorough collaborative hands-on exercises and multidisciplinary design activities. It then discusses obstacles to success such as increased preparation time and selling the concept to "old school" faculty. Finally, it addresses student and faculty reactions to a student centered active classroom and the positive outcomes of implementing an active learning environment for students of engineering.

Introduction[1]

Until recently, most engineering education has focused on imparting a certain abstract body of knowledge. This education was designed to move students to a point where they are capable and competent in the use of the principles and techniques needed to solve engineering and design problems. However, minimal effort has been put into making the problem solving activities relevant, interesting, challenging, and fun. Engineering education has traditionally been very analytical. Only a small amount of educational time is spent on hands-on design activities. It is, in fact, these hands-on design activities that most incoming students perceive as "engineering", not sitting in a classroom listening to someone talk about engineering. Some students are quickly disillusioned and discouraged when their first exposure to engineering is only classroom lecture. What is needed is some sort of hook - something to inspire, build confidence, and give them a window to the excitement of engineering practice. The hands-on early design activities that were piloted in fall semester 2000 directly addressed this issue. Piaget has emphasized that, “Certain conditions must exist if we are to reform education in a way that will answer society’s need for scientific training. The first of these conditions is, of course, the use of active methods which give broad scope to the spontaneous research of the child or adolescent and require that every new truth to be learned be rediscovered or at least reconstructed by the student, and not simply imparted to him”[2]. Active learning is more engaging and stimulating. Our goal is to educate excellent engineers by engaging students through inspiration, example, and by giving them access to relevant and interesting in class activities rather than using lecture methods alone.

First year students today tend to come in with good “virtual” skills but with limited tinkering and hands-on experiences with devices and consumer products. The results of a survey given to all 1200 incoming engineering students for the past two summers during orientation support this assertion. Questions related to computer use drew an average of 85% positive responses. Questions related to mechanical experience drew only 45% positive responses.

Engineering by its nature is design and creation. By definition, “engineering takes the knowledge of mathematics and natural sciences gained through study, experience, and practice and applies this knowledge with judgment to develop ways to utilize the materials and forces of nature for the benefit of all humans”[3]. The ABET EC 2000 guidelines demand that engineering graduates have certain problem solving, communication, and design skills.

It is necessary to teach principles and techniques to have the tools needed to solve problems and create viable design solutions. It is equally important to see the problems in a larger context so that the starting point is clear and the evolution of the solution is illuminated. Leonardo daVinci, although a great observer of nature, had no formal education, yet he never hesitated to design and construct significant mechanical devices.

In life, we notice that people tend to spend time and are engaged in activities that are interesting, challenging, and fun. As Maria Montessori has observed, “It is true that the teacher or lecturer has an ever more important role to play as culture reaches higher levels, but this role consists rather in stimulating interest than in actual teaching. When children are interested in a subject they tend to spend a long time studying it, or in other words, trying to find their way in it until they reach a kind of "maturity" by means of their own experience”[4]. This is as true for kindergarten as it is for graduate education.

Our challenge as educators is to create within our learning environment the spirit that is within our discipline, to create educational opportunities that are engaging for the students. The challenge is to engage students in that way that they become the inquirers, the searchers and the discoverers of solutions. We are products of our education and upbringing. We are self-selected as university faculty (hard working, studious, textbook oriented individuals). Our students have different backgrounds and interests. We must evolve and develop methods that engage our students or risk loosing them.

As Kolb has pointed out, “In the field of higher education, there is a growing group of educators - faculty, administration, and interested outsiders who see experiential education as a way to revitalize the university curriculum and to cope with many of the changes facing higher education today”[5]. The introduction of active learning opportunities is a way to incorporate direct experience in the classroom. SUCCEED and other university coalitions have funded and promoted many initiatives dealing with active learning in the classroom. Pioneering work by Siegfried Holzer[6], Karl Smith[7], Richard Felder[8], and others have revolutionized classrooms and illuminated the way for the rest of us to follow.

A first year elective laboratory course has been offered for several years at Virginia Tech. This laboratory was modeled after similar mechanical dissection laboratories initiated by Dave Ollis of NC State and Sheri Shepard of Stanford. At Virginia Tech there are enough sections for 256 of roughly 1200 total of the incoming engineering students. This laboratory introduces them to engineering by using a hands-on approach. This laboratory offers them an experience of how products are designed and assembled. The main drawback of this approach is scalability. We offer this course to nine sections of 32 students each. This still only reaches 20 percent of our entering engineering students. To address the issue of offering active learning opportunities to all entering freshman, we have worked to develop activities that could be offered during the regular class time rather than as a separate laboratory.

Pilot Project[1]

Development and implementation of any significant change in course delivery method, in this case hands-on early design activities, for the entire entering engineering class at Virginia Tech requires significant planning and trials. There are usually thirty-six sections of EF1015 offered fall semester taught by twelve instructors. Getting the entire faculty to “buy into” such a change required a successful pilot program. The creation of these activities had been proposed and investigated by professors Goff and Connor. We proposed that a pilot of our eight sections of EF1015 would be involved in active learning opportunities and assessed compared to a similar number of sections taught in the conventional manner. The proposal for the introduction of early design activities was selected for funding under the National Science Foundation’s SUCCEED (Southeastern University and College Coalition for Engineering Education) program. The Student Engineers’ Council at Virginia Tech (SEC) provided the funding for the Early Design Kits. The SEC is an organization of all levels and disciplines of engineering students. These students saw the value of this hands-on early design approach in the first year course. As a result of this support, eight activities for the pilot were created as shown in the following table:

Hands-On Activity	Title	Lesson Number	Hands-On Kits
1	Density 1	4	Shaped block, scale, tape
2	Density 2	5	
3	Archimedes’	6	Water container, block, tape
4	Pace Data & Graphing	12	Tape

5	Forces	18	Spring scales, weights
6	Moments	19	Yard stick, fulcrum, weights
7	Mechanics	21	Rod, spring scales, weights, cables
8	Electrical	25	Circuit board, multimeter

Table 1. Pilot Active Learning Activities

Each of these activities are designed to be a maximum of 20 minutes in duration and require teams of four students to review a paragraph of introductory material and then gather data to solve a practical engineering problem such as finding the density of a geometrically complex block of wood using a tape measure, and a postal scale. After the hands-on portion is completed, the students have several questions about the experience that they complete for homework. Each experience is designed to introduce and explore, in a very practical way, the concepts presented in the daily lecture material. These activities vary the rhythm of the class and give students an opportunity to be actively engaged in the learning process. The hands-on kits consist of eight sets of each experiment. Kits are located in secure boxes in the classroom so that they are always available for use.

As samples, the first and third activities are presented in their entirety:

EF 1015 Hands-On Early Design
Fall 2000
Activity 1 - Density Lesson

Background

Density is the mass of a material divided by its volume and specific weight is force (weight) divided by volume. SI units are kg, m, N, and seconds. English units are slugs, feet, lbf (pounds force) and seconds.

Equipment: Ruler, Postal scale, Object

Find

Determine the following in both SI and English units

1) Density of object
2) Specific weight of object
3) Surface area of object
4) Specific gravity

Class work

As a group, create a rough sketch and measure all required quantities

Homework

As a group and using standard engineering format determine the above properties.

EF 1015 Hands-On Early Design
Fall 2000
Activity 3 - Archimedes' Lesson

Background

According to Archimedes' principle, the buoyant force on an object wholly or partially immersed in a fluid at rest is equal to the weight of the fluid displaced.

Equipment

1) Wood block with 0.1" calibrations
2) Container of water

Find

1) The specific gravity of the wood by placing the block in water and noting the depth to which it sinks

Discussion

1) What is the vertical force (i.e. weight) of the floating block?
2) What is the vertical force of the water?
3) Estimate the specific gravity of the human body
4) A rowboat is carrying a large cannonball. The cannonball is dropped over the side. Does the water level rise, fall, or stay the same?
5) The block is floating in the Atlantic Ocean. Does the block float higher, lower, or at the same level as in our test container?

Full Implementation of Active Learning Activities

The syllabus for fall semester 2001 was modified to include a formal active learning opportunity roughly one each week for about half the semester. On the first day of class, teams of four students were formed. These teams were given tools and two devices, a pullback car and a friction car. Students were asked several questions about the cars and disassembled one of the cars. This marked a radical turning point for our first engineering course. This hands-on team experience created an environment where students could meet each other, interact, and engage in an active learning experience. The tone was set for the course. Students saw first hand that the course would be interesting and engaging. They also realized that they would enjoy the learning process.

As a result of a decision to alter the course to cover fewer topics in more depth rather than attempting to cover so many diverse topics, some of the activities were changed from the activities piloted in 2000. For instance, material balance and forces would be treated in class long active workshops with little or no formal lecture.

The following is a table of the fall semester 2001 activities:

Activity	Title	Lesson	Kit Items
1	Pullback & Friction Car	1	Pullback Cars
2	Fatigue Data Gathering	3	Large Paper Clip
3	Pool Noodle Surface Area	3	Pool Noodle
4	Density	5	Block, spring scale, ruler
5	Data & Graphing	11	Clock
6	Archimedes' Principle	26	Water container, block, ruler
7	Material Balance	27	Screen, gravel, sand, spring scale
8	Forces	28	Spring scales, weights

Table 2. Pilot Project Activities

The following is handout of the activity for the first day of classes: This activity was created by the coordinator of the EF1015 course, Dr. Jean Kampe.

Take Apart – Pull-Back Car

EF1015: Lesson # 1 Fall 2001

IN CLASS:

1. Things your group should have: 1) a small pull-back car, 2) a larger vehicle, 3) a plastic plate (for a take-apart tray), 4) a set of 4 small screwdrivers, and 5) two zipper plastic bags
2. Before you take it apart, look at your pullback car. *What features or abilities does it have?*
3. Remove the small screw, and take off the outer car shell. Look at the features again, observing the motion of the visible gears.
4. Pull down on the front end, lift out the white gear compartment, and (on the plastic plate) pry it open with a flat-blade screwdriver. Most of the gears will spill out of the casing, but the largest should remain in place. Rotate that gear to see what happens. Now remove it to see what it does.
5. OK, switch gears (ha, ha), and look at the larger vehicle (DO NOT take the larger vehicle apart!) *What does it do?*

6. One way to measure the overall "gear-up" ratio in a mechanism like the one you see in the larger vehicle is to count the number of flywheel rotations produced by one rotation of the vehicle wheels. Find the markings on your vehicle and do that.
Gear-up ratio = (number of flywheel rotations) / (number of wheel rotations) = ________
7. Return all the pullback car pieces to your instructor in the small zippered plastic bag. Put everything else in the other, larger plastic bag, and return it to the classroom box.

OUT OF CLASS, on green paper

1. Briefly, what is the mechanism that makes the little car move forward after being pulled backward?
2. What property of matter is used in the design of the pullback mechanism?
3. What is the mechanism that keeps the larger vehicle moving after you let go of it?
4. What property of matter is used in the design of the larger vehicle's mechanism?
5. Which mechanism is the more efficient design in terms of your input energy?

Results and Conclusions

After a presentation of the activities to the faculty, the majority agreed that these active learning opportunities would be a valuable contribution to the learning process. Funding was provided again from SUCCEED to revise the delivery method of the first year courses to include these activities. Fall semester of 2001, students in all 36 sections of EF1015 were exposed to a sequence of team collaborative active learning opportunities.

A questionnaire to assess student perceptions of learning was given at mid-semester and at the end of the fall 2000 semester to eight hands-on (HO) sections and ten traditional (TR) sections.[9] A discussion of the end of semester results of the HO students versus the TR students follows:

The statements that the students responded to were:
1. The thought of a career in engineering is exciting
2. I am learning in this class
3. This class has helped me understand engineering
4. This class is relevant
5. This class is useful

For the first five statements the HO students consistently responded more favorably than the TR students. A pooled t-test was used, at a 5% level, to determine if a significant difference of opinion existed between the HO and TR students. The significant differences were:

- The HO were significantly more exited about engineering. (0.9%)
- The HO perceived that they were learning more. (4.9%)

In conclusion, the collaborative active learning opportunities met the goal of increasing motivation and appeared to meet the goal of increasing student learning. At the end of the pilot semester, the hands-on students were significantly more exited about engineering than the traditionally taught students. Also at the end of the semester, the hands-on students, in comparison to the traditional lecture students, felt they were learning more.

Three of the six Course Objectives of EF 1015 are for students to be able to a) apply the engineering method to problem solving, b) apply basic physical and mathematical concepts to introductory engineering problems, and c) translate "word" problems into the mathematical statements that describe the physical situations presented; i.e., read, or listen to, problems and understand them. The objectives of the collaborative active learning opportunities support these learning objectives. Giving students physical problems to solve with little instruction, in addition to augmenting written or oral problems, creates a situation where students must invent the path to the solution.[10]

In addition to organized collaborative hands-on exercises, brief active group work interspersed with each lecture works well to reconnect the students with the material and give them the opportunity to learn from each other. Lengthier team design activities combining students from other disciplines is also an effective learning methodology. Collaborative design activities between Engineering students and Industrial Design students have been highly effective.[11]

Even though collaborative active learning has been very well received by students and most faculty members, there are still those faculty members that cling to old delivery methods and the notion that anything other than lecture delivery of material is weakening the strength of the course. It is very important to educate faculty and allow them time to buy into the process. It is also true that an active classroom requires much more thoughtful preparation time. However, students universally receive "student centered" learning as an overwhelmingly positive change. The reactions of the students involved in the active classrooms were very encouraging. Comments ranged from "this is the most interesting class I've had" to "it was hard, but I had fun and learned a lot".

Some of the more common problems were: making sure that 80 identical replications were available for teams of students in all sections of our classes; preparing faculty in weekly meetings so that they had experienced the exercises themselves and were ready to deliver the activities to their classes; and managing class time for lecture time as well as active learning time. One faculty member commented "I haven't been so excited to go into my class in years". The overall level of enthusiasm for teaching our introductory courses was very high this year. Logistics and overall faculty commitment to the concept seemed to be the two major issues of implementing active learning.

A survey was given at the end of fall semester 2001 asked 1200 students and 13 faculty members several in depth questions about the hands-on active learning that occurred during the fall semester. The results of this survey are not fully available at this time, but a preliminary examination of responses shows clearly that the active classroom approach was a huge success among both faculty and students.

What I hear, I forget; what I see, I remember, what I do, I understand. – Chinese proverb

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