Hands-On Experiences in the First Year Engineering Classroom

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Abstract

To paraphrase Piaget, "In order for a child to understand something she must construct it herself, she must re-invent it". Engineering students today tend to arrive with very good math and science skills, but limited practical experience. A questionnaire given to all 1200 incoming engineering students this past summer strongly supports this assertion. Chalk and talk instruction is not as effective as it once was when students came in with practical experience whether it was from working on cars, working on a farm, baking bread and cookies, or tinkering with model airplanes. Today's students are web wired wizards, but ask them to attempt one of the above activities and few have the confidence or know how to begin. Today, there is a strong need to supplement lectures with hands-on activities. To address this need and to present a more inductive approach to engineering education, we presented several hands-on, collaborative, experiences during the semester in our first semester Introduction to Engineering lecture classes. These activities are 20 minutes in duration and require teams of four students to review a paragraph of introductory material and then 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 lecture material.

The paper will discuss the need for hands-on activities, the difficulty in implementation in a large (1200 students), freshman program and the rationale for the choice of activities. We will provide a list of the activities with their goals and compare these with the goals of the traditional lectures. Further, we will discuss the lessons we learned in the pilot project of eight sections of 32 students each as well as the goals for scaling up this program up for 36 sections of 32 students taught by 12 faculty members.

Introduction

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 activities. It is, in fact, these hands-on activities that most incoming engineers 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 actual engineering practice. The hands-on early design activities that we piloted this semester directly address 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" [1]. Our goal is to educate and guide engineers to excellence by retaining students through inspiration, example, and by giving them access to relevant and interesting in class activities rather than through purely lecture methods. Our challenge as teachers is to infuse our instruction with the spirit that is within our discipline, to create lessons that are engaging for the students.

The Notion

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. An internal survey that was given to all 1200 incoming engineering students this past summer strongly supports this assertion. Four computer related questions drew the following percentages of positive responses:

1. In the past year have you had a person e-mail address? 89%
2. During the past year have you had access to a personal computer in your home with a connection to the internet? 91%
3. Have you used a personal computer for anything other than word processing, games, email or web browsing (examples: programming, spreadsheets, creating graphics, website design)? 73%
4. Have you ever installed software in a personal computer? 84%

Four mechanical related questions drew these positive response percentages:

1. Have you ever installed a hardware component inside a personal computer? 47%
2. In the past four years have you reduced a mechanical device to a set of parts that you could not reassemble? 48%
3. Have you changed the oil and oil filter in an automobile? 52%
4. Have you worked on the engine or transmission of an automobile? 30%

As Kolb had 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" [2]. The introduction of hands-on early design activities in class is a way to incorporate experiential education in the classroom.

An ongoing attempt to bring practical experience to the first year engineering students has resulted in the creation of a first year elective course at Virginia Tech for some (256 of 1100 total) of the incoming engineering students to introduce them to engineering by using a hands-on approach. This laboratory class employs a combination of reverse engineering of consumer products and design case studies. The aim is to introduce our students to engineering and design and to generate a first hand appreciation of the discipline. At the same time, students acquire basic hand skills using wrenches, calipers, and other basic hand tools, they experience how products are assembled and designed.

The main drawback of this approach is scalability. We offer this course to eight sections of 32 students each, but this still only reaches 20 percent of entering engineering students. To address the issue of offering hands-on early design activities to all entering freshman, we have recently developed eight activities that could be offered during the regular class time in our first required introduction to engineering class rather than as a separate laboratory.

Background

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].

It is necessary to teach these principles and techniques to provide students the tools to solve problems. 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. In fact, the vision of the problem context and intuitive solution precedes any specific principles of solution. Leonardo daVinci, a great observer of nature, although he had no formal education, 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, dare we say it, fun. *Fun is not a four-letter word.* 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].

Why did practicing engineers go into engineering or design in the first place? If you think back, it was because something or someone inspired us to notice that the activity was interesting, challenging, and fun. We didn't pursue the profession thinking that it was going to be long hours working obscure problems on paper or computer. Goff chose to study aerospace engineering primarily as a result of he and his dad having such a great time building and flying model airplanes when he was a child. He chose the profession because he saw that engineering was a creative endeavor. Understanding how things worked, modifying them, creating products that work - this is what he was interested in.

Our challenge as teachers is to infuse our instruction with the spirit that is within our discipline, to create lessons that are engaging for all the students. We are very good at transmitting technical information. However if students learn all this information, but do not have a hunger for seeing the larger picture, the synergy, and a desire to learn more, of what value have we been? Shifting student attitudes from "what is the assignment and how can I get it done" to "Wow, this is interesting! What's the best approach and how does this relate to solving engineering problems", should be our goal.

We are products of our education and upbringing. We are self-selected as university faculty (hard working, studious, textbook oriented individuals). Change is most times difficult. However, we must evolve or risk loosing the life-blood of our profession – our students.

The Project Pilot

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 thirty-six sections of EF1015 offered fall semester taught by twelve faculty members. 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 exposed to the hands-on early design activities 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 Southeastern University and College Coalition for Engineering Education (SUCCEED) program. The Student Engineers' Council (SEC) at Virginia Tech funded the hands-on kits. The SEC is an organization of all levels and disciplines of engineering students. They saw the value of this hands-on 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

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, third, seventh, and eighth activities are presented in their entirety in the appendix.

Results

Three of the six Course Objectives of our first introduction to engineering course, 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 Hands-On Early Design activities 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.

The results of this pilot were positive. Students' perception that they are learning more and that the class is helping them learn engineering is significantly higher than responses from students in the standard classes. The quantitative and statistical details of this pilot study are presented in another paper.

After a presentation of the activities to the faculty, the majority of the faculty members agree that these hands-on early design activities are a valuable contribution to learning. Funding is forthcoming to revise the delivery method of the course to include these activities. Beginning in fall of 2001, students in all 36 sections of EF1015 should be exposed to hands-on early design activities.

Bibliography

1. Piaget, J., To Understand is to Invent : The Future of Education Grossman Publishers 1973, pg 15

2. Colb, D.A., Experiential Learning: Experience as the Source of Learning and Development, Prentice-Hall 1984, pg 4

3. Eide, A.R., Jenison, R.D., Mashaw, L.H.,& Northup, L.L, Engineering Fundamentals and Problem Solving, 3rd Edition, McGraw-Hill, 1997, pg 4

4. Montessori, M., Childhood Education, New American Library,[1975,c 1955], pg 55

Appendix

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

1) Ruler
2) Postal scale
3) Object (A wooden block with interesting geometry)

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

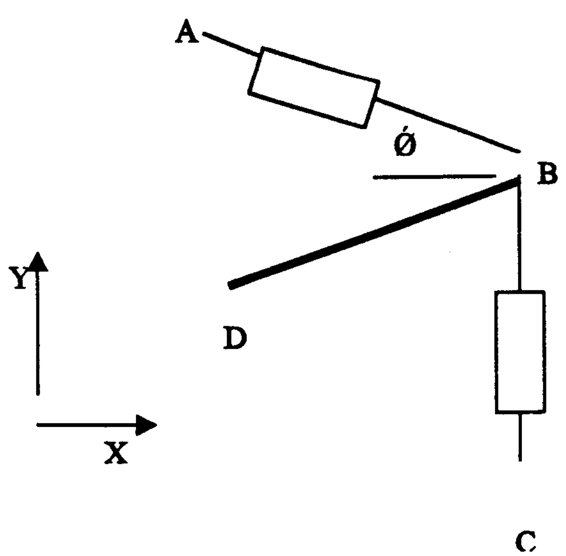
Discussion

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?

EF 1015 Hands-On Early Design
Fall 2000
Activity 7 - Mechanics Lesson

Equipment

1) Two spring scales
2) Stick DB
3) Water bottle
4) Tape measure



Setup

1) Determine the weight (N) of the bottle of water
2) Use the red spring scale along AB
3) Use the brown spring scale along BC
4) Hang the water bottle at C
5) Stand near a wall to prevent excessive movement in the Z direction and to use a mortar joint as horizontal

Class work

1) Repeat the following for 6-8 values of Ø
   a. Measure the X-component of distance AB
   b. Measure the Y-component of distance AB
   c. Note the reading of the red spring scale
   d. Note the reading of the brown spring scale

Homework

1) As a group and using full engineering format
   a. Create a table of force AB, force BC, and the reaction at pin D with respect to Ø
   b. Plot Ø (independent) vs. force AB with Ø varying from 0 to 90°

EF 1015 Hands-On Early Design
Fall 2000
Activity 8 - Electrical Lesson

Background:

From Ohms Law we know that Resistance equals Potential divided by Current or E=IR.
Additionally, Kirchhoff's Laws add the following:
Kirchhoff's Current Law - KCL

- The algebraic sum of all the currents at any node in a circuit equals zero.
- In a circuit consisting of n nodes, n-1 independent current equations can be derived from KCL.

Krichhoff's Voltage Law – KVL

- The algebraic sum of all the voltages around any path in a circuit equals zero.

Equipment:

1) Circuit Board with power supply and various resistors
2) Multimeter – Make sure range is set correctly and probe input is correct before connecting to circuit board.

3) Color Code chart for Resistors

Find:

1. Sketch Schematic of circuit board.
2. With Switch off, unclip red, green, and black clips:
a) Measure and record each resistor value and verify with color code chart.
b) Verify by calculation that resistors in series follow Rt = R1 + R1 + R3.
c) Verify by calculation that resistors in parallel follow 1/Rt = 1/R1 + 1/R2.
3. Reconnect Red Clip and close switch to complete circuit in first loop:
Quickly measure potential of battery power source and voltage drop across each resistor in first loop to verify KVL.
4. Open Switch – Change input on Meter to Current and set range to 200 mA:
Measure current in first loop and mathematically verify E= IR.
5. Reconnect Green and Black Clips:
Measure current in each leg and verify KCL-sum of currents for Node A = 0.

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