

## Enhancing Student Engagement in an Electrical Engineering Course for Non-majors Using Project-Based Homework

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### Abstract

This paper describes major revisions made to an Electrical Engineering course for non-majors with the express purpose of increasing student engagement by replacing a significant portion of the traditional homework with hands-on projects to reinforce concepts. Projects included a small magnetic levitation system, audio filtering and amplifier circuits, a light meter, and a final project requiring control of DC and stepper motors to create a machine to lift and accurately deposit small objects. Strategies for efficient grading of projects are also discussed. Evidence of increased student engagement in the form of numeric and written course evaluation results are presented, as well as lessons learned from the implementation of these projects over a two-year period.

### Keywords

Project-based learning, electrical engineering survey, LabVIEW.

### Introduction

Teaching Electrical Engineering concepts to students from other majors carries with it significant challenges including low student motivation, insufficient time to cover material in depth, large class sizes, and difficulty in convincing students that the material is relevant to their career interests<sup>1</sup>. A number of educators have attempted to leverage the advantages of active learning techniques<sup>2</sup> to increase student motivation and engagement in non-major Electrical Engineering courses. One such attempt<sup>3</sup> incorporated a project-based approach and reported gains in student perception of hands-on and design skills. Another approach<sup>4</sup> incorporated a robotics project using LabVIEW programming on a Lego Mindstorm platform. At Grove City College, ELEE 210 is the “Survey of Electrical Engineering” course taken by non-majors, typically Mechanical Engineering and Industrial Management majors. It is a 3-credit lecture-based course, normally carries an enrollment of 40 to 50 students, and has no accompanying laboratory. It can be a difficult course to teach due to the challenges mentioned above. Student comments on course evaluations from previous years revealed a significant number thought the course material was important but were dissatisfied with the learning outcomes achieved. Several indicated a desire for hands-on experiences to help reinforce course concepts. Below are a few selected comments from ELEE 210 student course evaluations in 2008 and 2009 before the measures described in this paper were enacted.

- “I wanted this course to be helpful, but I was not able to glean much from it.”
- “This class could be very valuable for mechanical engineers if it was more hands on and less theoretical.”

- “I think this course is important as a mechanical engineer, however, I unfortunately learned very little.”
- “More hands-on or lab type experience would help to better relate the concepts we are learning to something we can understand or see.”
- “It would have been helpful to have a lab, but we did not, at least one or two lab exposures throughout the year would have made a huge difference in my actual understanding of the applications of this course.”

In an attempt to enhance student engagement and achievement of learning outcomes, major revisions of course assignments were introduced when the course was taught in 2010. Although traditional exams and graded homework were still assigned, a significant portion of the homework was replaced by hands-on projects requiring application of the concepts learned in class lectures. Students collaborated on the design and implementation of these projects in groups of two to four.

### **Hardware**

Since the class had no time or space allotted for official laboratory sessions, the decision to add projects meant that students needed to have portable hardware kits that could be used anywhere. In addition, many of the more interesting project ideas required a programmable controller. The controller chosen was the USB-6009 (\$300) from National Instruments. The main reason for the choice of the USB-6009 rather than less expensive controllers such as the Arduino was that most of the students had a very limited background in programming, and there was no room in the course for extended training in microcontroller hardware and software. A very accessible controller was needed that abstracted many of the low-level I/O tasks common to microcontroller systems. The USB-6009 provided the I/O capabilities needed for projects, and LabVIEW running on student laptops provided programmability and display capabilities. The USB-6009 is powered from a standard USB bus, enabling students to work on projects anywhere they had access to a computer with a USB port. It has eight analog inputs with up to 48 ksamples/sec sample rate, two 12-bit analog outputs, a 32-bit counter and twelve bidirectional digital I/O pins.

In addition to the USB-6009 controller, a kit of inexpensive electronic parts was loaned to each team of students. Included in the kit were a breadboard and wire kit, an assortment of resistors, capacitors, LEDs, a MOSFET, a Hall Effect sensor, a small DC gear motor, a small stepper motor, a mini audio speaker, a solenoid, and an assortment of integrated circuits including H-bridge motor drivers, comparators, digital counters, and op amps. A complete list of parts is available from the author upon request.

### **Projects**

Attempts were made to create hands-on projects that students would find motivating due to their direct relation to concepts studied in class and/or devices they were accustomed to using in daily life, had relatively low hardware cost, and could be accomplished with the level of knowledge gained in this introductory class. Importantly, one additional criterion for project selection was that each should feature a quick way to assess effective application of design skills using

objective performance criteria. A grading rubric based on these performance criteria was shared with the students when the project was assigned, which made grading easy and efficient.

Here is a list of the projects:

1. Design of an adjustable voltage divider using a potentiometer and two resistors. Output voltage displayed in LabVIEW.
2. Design of an op-amp circuit accepting a voltage input from an IC temperature sensor and converting to a 0-5V range representing normal human body temperatures.
3. Design of a light meter using a photoresistor and calibrated display in LabVIEW.
4. Design of a simple op-amp control circuit to drive current through an electromagnet to magnetically levitate a permanent magnet.
5. Design of active low-pass and high-pass filters using op-amps. LabVIEW was used to generate the audio input signal to the filters and display the resulting gains in dB over different frequencies. A small, inexpensive speaker was used to audibly reveal the filter characteristics.
6. The final project was a class contest involving the design of a machine to pick up ball bearings from a petri dish and distribute them in three different paper cups located nearby. The design incorporated the use of two different small motors (one DC motor and one stepper motor) contained in the hardware kit. Below is an excerpt from the assignment:

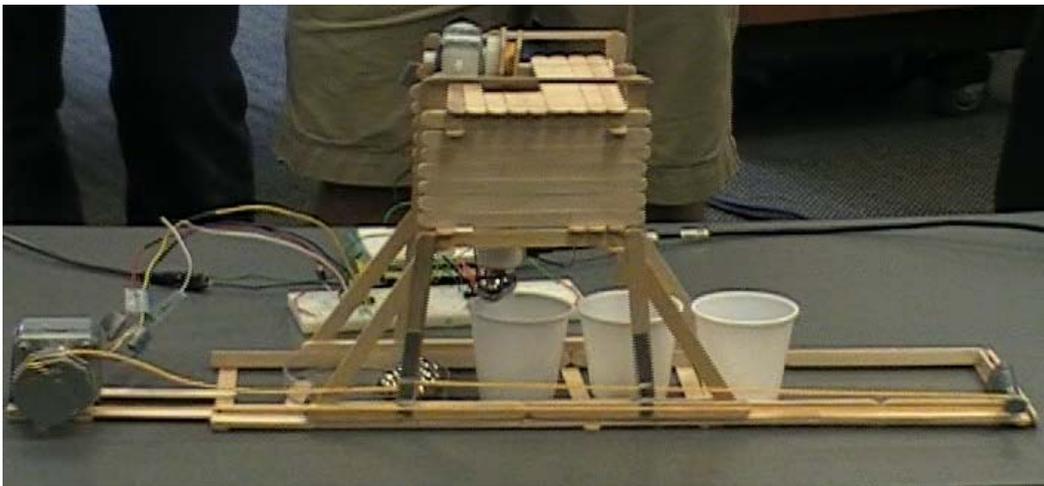
*Using the items in your kit, LabVIEW software, and an unlimited supply of popsicle sticks, glue, rubber bands, string, and duct tape, design and build a machine that can pick up and deposit ball bearings in plastic cups without spilling them, according to the parameters described below.*

- *The game system will consist of the following components:*
  - *Plastic petri dish containing 12 ball bearings. You may place your petri dish anywhere you wish with the restriction that at least some part of it must be touching the table top at all times.*
  - *3 plastic cups located wherever you wish, except that no part of any cup may be located below the table top at any time.*
  - *A machine of your design built on the table top, not **initially** in contact with any of the ball bearings.*
- *At a “go” signal from the instructor, your machine will have 2 minutes to transfer as many ball bearings as possible from the petri dish to the cups.*
- *Scoring:*
  - *(1 point each) for ball bearings located in cups at the end of the round.*

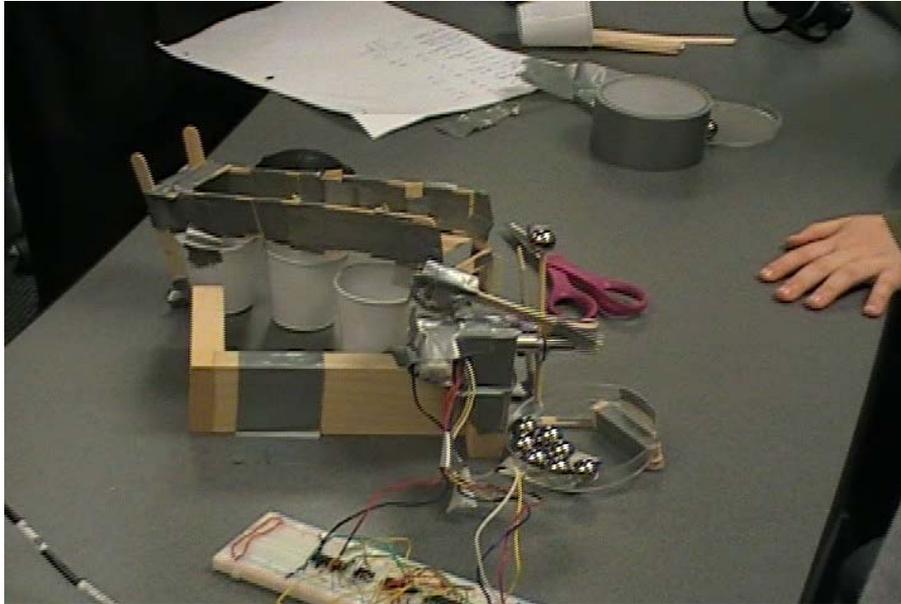
- (5 points) if at the end of the round there is at least one ball bearing in two different cups.
- (10 points) if at the end of the round there is at least one ball bearing in all 3 cups (note: you can get points for fulfilling b or c but not both).
- (-1 point) for each ball bearing not in the petri dish or one of the cups at the end of the round.

## Results

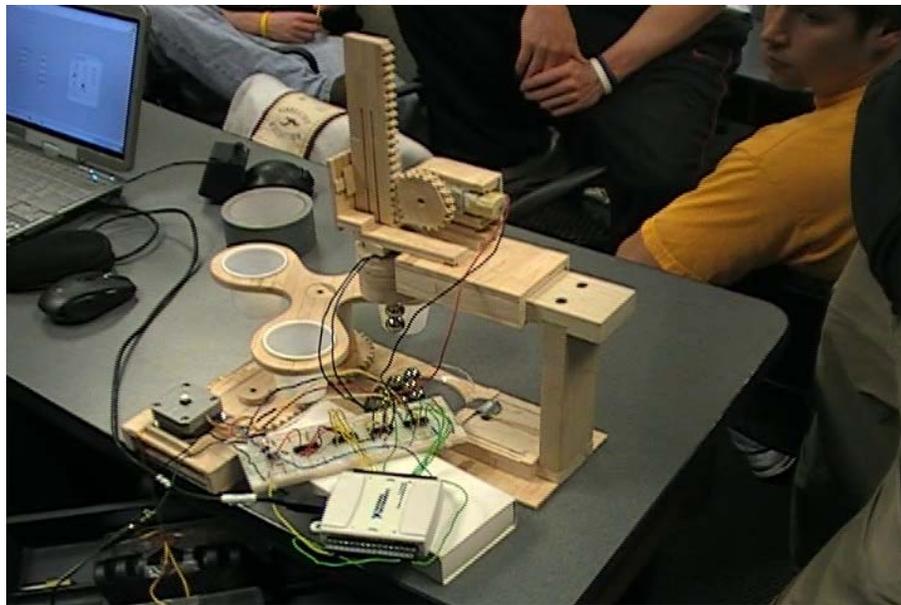
The variety and creativity displayed by the students in their project designs was impressive. In 2010, 96% of the student teams satisfied all the objective performance criteria for all the projects and achieved a perfect score. In 2011, 99% did so. Following are a few selected photographs that represent the breadth of ideas and depth of effort that students invested in the final project.



**Figure 1. Gantry Design Moving on Tracks**



**Figure 2. “T-ball Bat” Design**



**Figure 3. Geared Elevator and “Lazy Susan” Design**

Informal discussions with students on the last day of class suggested that the project assignments fulfilled the original goals of reinforcing class concepts with hands-on learning and increasing student engagement. This conclusion was corroborated by numeric results from student course evaluations, and by written comments made by students on those evaluations. The student course evaluation question that most closely measured student engagement was a 7-point Likert-scale question asking “Where appropriate, has this professor challenged students to think about the subject matter in depth?” The average rating over the two years these projects were implemented was 6.38/7.00 (77 student responses). When asked “What is your overall

assessment of this course?” the average rating over two years was 5.99/7.00 (75 student responses). Students made many positive comments concerning the projects as well as some negative ones. Following is a sampling of student comments:

- “The projects were well designed and demonstrated a variety of the applications in which the topics from class are used. The projects were both interesting and fun to design.”
- “I liked the projects for the most part. They were fun and really helped me understand the application of the class material. My non engineering friends were always envious of the cool projects we built.”
- “The projects, though sometimes frustrating taught me a lot and in the end were satisfying to do.”
- “The projects in this class were outstanding. They were very interesting to work on and we had to grapple with new concepts as we implemented our designs. I especially liked the bolt levitation project as it helped reinforce what I had learned about operational amplifiers in class.”
- “the projects got very involved at times and they could have been cut back in their elaborateness.”
- “The projects were also a great way to learn the material, more of those would be great. They weren't too easy, and stretched us, but were a good way to learn.”
- “The projects were very beneficial to my understanding of the material.”
- “yeah. the labs really helped me learn what was up, but it was SUPER painful”
- “I loved starting a lab thinking there is no way I'm going to be able to do this, and then getting it working (with some help) every time.”
- “The projects are perfect for practicing what we learn in class.”
- “The projects helped us to take the ideas we learned in class and use them in a realistic application, which helped us to think of creative applications of a lot of the ideas.”

### **Conclusions and Future Work**

The main goals of introducing hands-on projects in ELEE 210 were to increase student engagement and to help convince students that the class material was relevant to their future careers. Evidence from student performance on the projects and student course evaluations suggest that these goals were met. Some students expressed that the final project was too challenging, and that it could be broken into smaller sub-projects which could be accomplished earlier in the semester. The author has not taught this class since 2011; however he plans to incorporate this revision at the next opportunity. In addition, the author is investigating the

possibility of offering an online version of this class, where hands-on projects will continue to be an integral part of the coursework.

## References

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