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Concept Learning Embedded in a Freshman Engineering Project on Energy Scavenging

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Abstract—**This paper describes a freshman engineering hands-on project where students design and build a vibrating system that is used to perform energy scavenging experiments. By working on this project students become familiar with important engineering concepts, such as signal amplitude and frequency, in a simple manner. They also gain experience and an appreciation of standard engineering design practices. The pre- and post-processing survey shows that students increase their basic understanding of basic engineering concepts. In their reflection papers most students expressed a great deal of satisfaction with the project. A common concern stated in those papers was the large amount of time dedicated to successfully complete the various required tasks.**

Keywords-freshman engineering, concept learning, energy scavenging

I. INTRODUCTION

Introducing to freshman engineering students basic concepts, such as gear ratio, spectrum, diodes, transducers, etc., is most desirable. Understanding these concepts will facilitate students to later on better appreciate the content of fundamental courses in their specific field, such as circuits and statics. However, these topics are too abstract for freshman students to readily accept them. Hands-on activities have several advantages over traditional methods when explaining this type of concepts [1]. In this paper, the development and implementation of embedding concept learning in a freshman engineering hands-on project is presented.

At our school, ENGR/ETCS 101 - Introduction to Engineering, Technology, and Computer Science is a one hour per week course specifically aimed to first year engineering and engineering technology students. The overall purpose of this course is to prepare students for a successful academic performance, to introduce the engineering field, and to make them aware of the engineering problem solving strategy. Students are asked throughout the semester to read material in their textbook [2] and other sources and write memos and essays. They are also given a series of lectures about particular engineering and technology fields of study. To gain an understanding of professional ethics they are also asked to use the engineering code of ethics and apply it to a real case. This semester the case was the I-35W bridge collapse in Minnesota that took place in 2007 [3].

When ETCS/ENGR 101 was first launched (in 1999) students were asked to design, build, and test an autonomous robot using the Lego Challenger set (similar to the Lego Mindstorms set) that had recently become available. This project proved to be very successful and played an important role in improving the retention of engineering and technology students [4]. The project was discontinued in 2003 because the faculty involved with the course moved into different academic roles and there was no one else in the faculty with the expertise and desire to continue having such project in this course.

This is now 10 years later than when this course was introduced and a new type of project more in tune with contemporary times is needed. The topic of scavenging energy from the environment is an area that the faculty assigned to teach this course had been exploring for their own research interest. Therefore having a project in this area not only fell within their academic interest but it also has a great deal of societal impact. This type of project also fits very well with the requirements of the IEEE Program Real-World Engineering Projects (RWEP) that funds high-quality, tested, hands-on team-based society-focused projects for first-year students. These projects are designed to increase the recruitment, persistence to degree, and satisfaction of all students, and particularly women, in baccalaureate EE, CE, CS, BE and EET degree programs [5]. It was then decided, at the end of the 2008-2009 academic year, to reintroduce a freshman level design project in this course that at the same time can be proposed to the IEEE RWEP program. The following sections describe the project in more details as well as the experience gained from having it first offered in the fall semester of 2009.

The remainder of the paper is organized as follows. Section II describes the project. Section III shows the students' activities. Section IV presents the survey results on how well students understand a list of concepts as well a summary of the main comments from the student's reflection papers. Finally the discussion and conclusions are given in Section V.

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II. Description of the Project

In this project, students conduct energy scavenging experiments with a piezoelectric device. The project can be broke into the following steps:

1. Design and construction of a mechanical vibrating system
2. Experimental measurements, data acquisition and analysis
3. Use of an energy harvesting circuitry to charge a battery.

The design component of this project is the construction of a vibrating system that is used in the experiments on energy harvesting using a piezo buzzer. Each team designs two test stations that generate vibrations of different amplitudes and frequencies using: a DC motor, standard Lego bricks, Lego gears, shafts, cams, or equivalent pieces. Fig. 1 shows a sample of the components provided. Students had access to a larger amount of Lego pieces than the ones shown in Fig.1. In one of the testing station, a gear train needs to be designed for the vibrating system to match as closely as possible the given resonant frequency of a piezo buzzer. The DC motor used in this project is of low cost and can be easily bought from many sources.

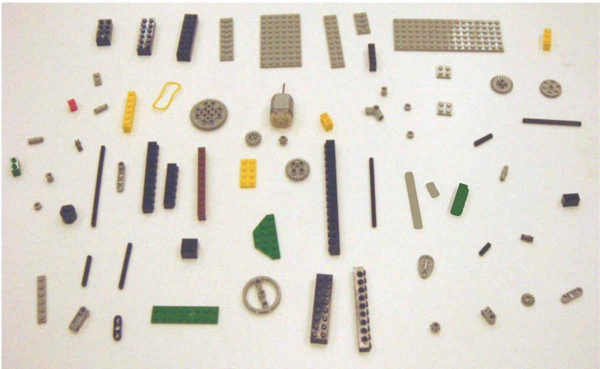

Figure 1. A Sample of the Components Provided to Students.

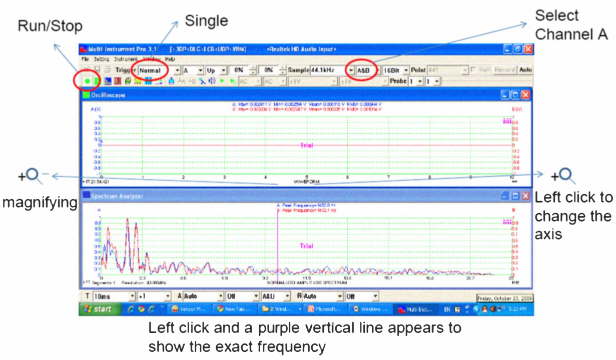

Figure 2. A Screenshot of the Virtins Multi Instrument Pro 3.1

The project calls for observing and measuring the various electrical signals generated. It was important to be able to do this task without the use of an oscilloscope since a requirement of the IEEE RWEP program was to minimize the cost of each station. It was decided to use software oscilloscopes which are available from several suppliers. The price of these software oscilloscopes is usually low (less than $30 per copy) but since they use the computer audio card (the microphone input) a special probe cable is needed which can be bought (around $30 per unit) or built at a much lesser cost. We decided to use the latter option which has the drawback of the labor time dedicated to make them and the need to use a voltage divider to have it work properly. For our project we used a decade resistor box, to implement a voltage divider, and the Virtins Multi Instrument Pro 3.1 as the software scope. Fig. 2 shows a screenshot with callouts describing the software functions.

The students worked in groups. They were given a technical description of what the project consisted of. They were asked to first brainstorm for a week and then suggest an initial design. After a critique of the initial design they were asked to build a prototype and carry-out the various measurements and analysis requested. They went through several iterations before a final design was used to charge the battery.

III. Student Activities

A. Student Activities

This is a group project. The whole class is divided into groups of 3 or 4. Fig. 3 shows pictures of students working on the project.

B. Project Timeline

The project takes 15 hours to accomplish. Two and a half hours are dedicated to the lectures that provide the necessary background information, instructions about the experimental measurements, and a summary. In our school, six weeks were allocated to the project, where in each week there is 50 minutes of class time dedicated to the project. Students still need to find time outside the class to build their design and conduct experimental testings. The timeline for students' activities expressed in hours is shown in Table I.

TABLE I. Timeline of Students Activities

Students Activities	Timeline
Initial Vibrating System Design	2.5 hours
Construction, Experimental Measurements, Tests, and Evaluation	8 hours
Report Writing	2 hours

C. *Student Built Vibrating System*

To ensure that this project was feasible the instructors built a prototype during the summer of 2009. Once a workable prototype was built and tested there was a good level of confidence that students would be able to design and build their own units with the components available to them. As it turned out, and not surprisingly, many of the prototypes built by the students had superior features to the ones built by the instructors. This project provide an opportunity for the students to experience the most important aspect of what is to be an engineer, that is, *to be able to design, build, and test something, and in doing so to be as creative as possible.* Fig. 4 shows two vibrating systems built by the students.

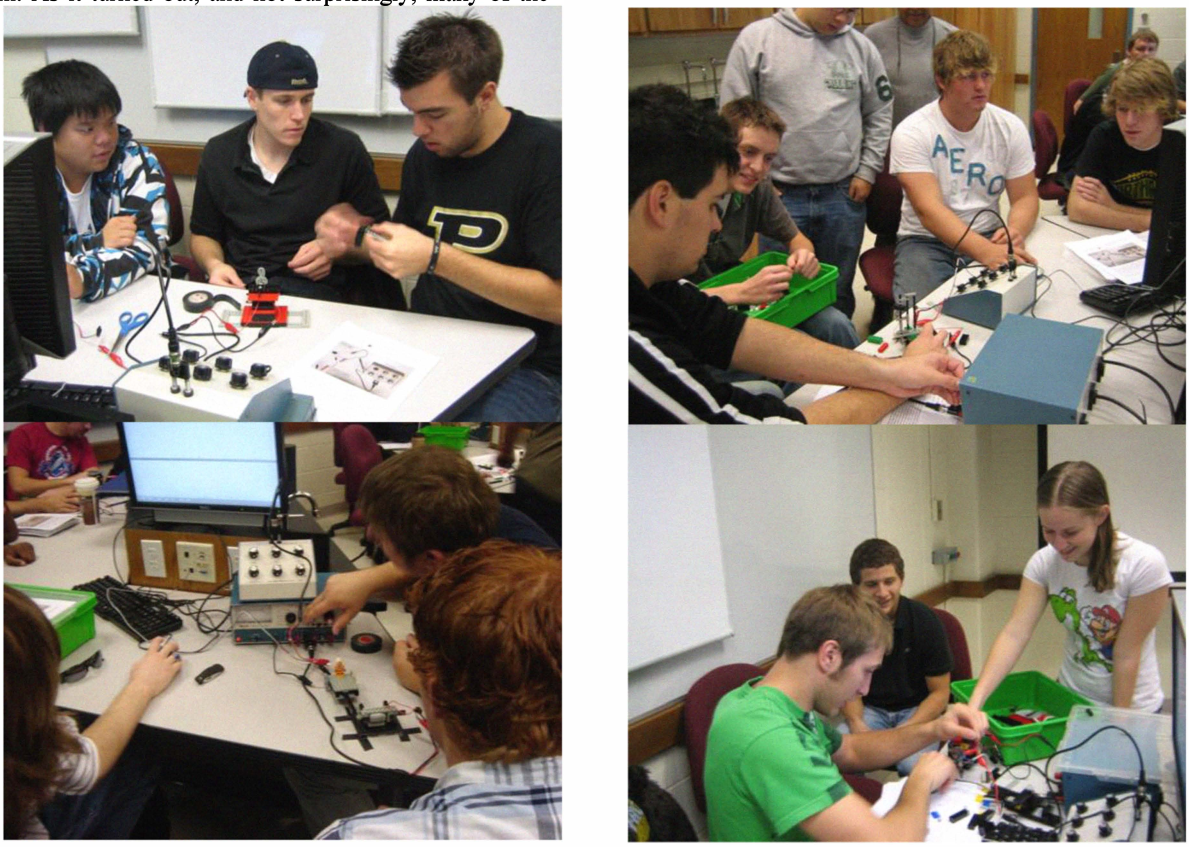

Figure 3. Students Working on the Project

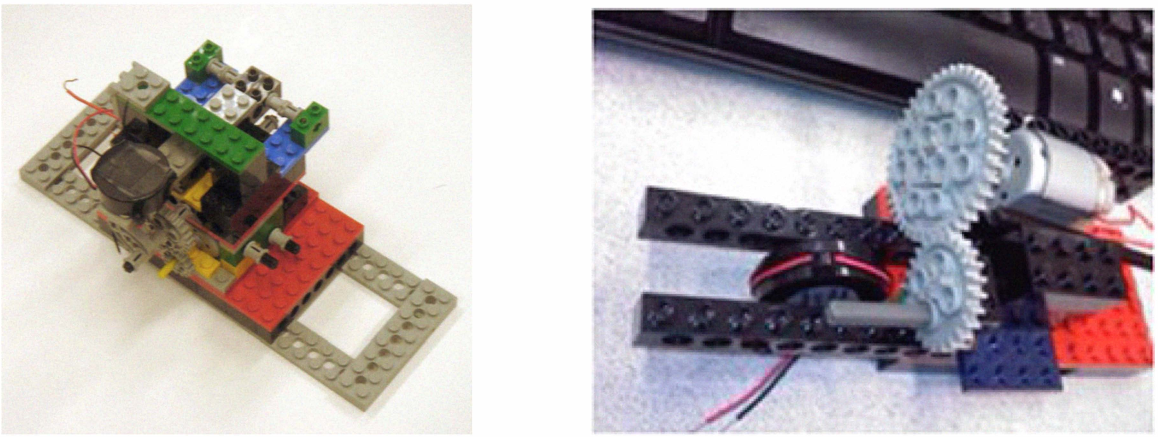

Figure 4. Two vibrating systems built by the students

IV. Survey Results

This project was implemented with over 100 students in five sections of ENGR/ETCS 101 in the fall of 2009. At the beginning of the project, a survey was given to students to describe their understanding of the following concepts, diode, AC vs. DC, gear ration, simple gear train, compound gear train, frequency, spectrum, asymmetric cam, signal rectifying, and harmonic vibration. Students were asked to rate their understanding over these concepts using a range of 1-5. After the project was finished, a post survey on the exact concepts was conducted for comparison. 113 students took the pre-survey. 117 students took the post-survey. The survey was given to students during the class time for a better return. Because not every student attended those two classes, the total numbers of students who took the pre- and post – survey are slightly different. The students were from the following majors, Electrical Engineering (EE), Computer Engineering (CmpE), Mechanical Engineering (ME), Civil Engineering (CE), Mechanical Engineering Technology (MET), and Industrial Engineering Technology (IET), as well as a few students from other majors. Table II shows the pre- and post-survey results. The results showed a significant improvement in understanding the concepts.

Most comments from the students' reflection paper about their experience in this project is positive. Students enjoyed the hands-on experience, made friends with the team members, and understood more about what an engineering field is like. A common negative comment from students was the large amount of work for 1 credit hour course. Currently the freshman engineering curriculum committee is working on revising the curriculum to move design content from another course to make ENGR/ETCS 101 a 2 credit hour course.

V. Conclusions

The development and implementation of a hands-on project in a freshman engineering course is described here. The project is used to introduce freshmen fundamental engineering concepts as well as principles of engineering design. The societal impact of the project, Energy Scavenging from Vibrations, also makes students more aware of what engineering can do to address current energy issues worldwide. Presently we are modifying the content of the project to address the main concern that many students expressed in their reflection papers, i.e. the level of complexity and the amount of time needed to complete the project.

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TABLE II. Pre- and Post- survey Results by Majors

	Civil Engr		Computer Engr		Electrical Engr		Mechnical Engr		MET		IET		Others		Total	
Number of Students	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
	18	16	7	9	17	14	41	41	14	20	1	1	15	16	113	117
Diode	1.9	3.3	3.0	3.6	2.1	3.5	2.0	3.3	1.5	3.4	3.0	4.0	1.3	3.4	1.9	3.4
AV vs DC	2.7	3.9	3.6	4.2	3.2	4.3	3.0	3.9	2.9	3.8	3.0	4.0	2.1	3.8	2.9	3.9
Gear Ratio	2.8	4.1	2.4	4.1	2.7	4.0	2.9	4.1	2.5	4.2	3.0	5.0	2.2	3.8	2.7	4.1
Simple gear train	2.4	4.2	2.0	4.0	2.4	3.7	2.7	4.1	2.4	4.0	1.0	5.0	1.9	3.9	2.4	4.0
Compound gear train	2.1	4.1	1.6	3.7	1.6	3.4	2.2	3.9	2.1	3.7	1.0	5.0	1.5	3.9	1.9	3.8
Frequency	3.6	4.2	3.7	4.2	3.2	4.2	3.2	4.0	2.8	3.8	3.0	5.0	2.6	4.3	3.2	4.1
Spectrum	2.9	3.1	2.9	3.3	2.5	3.5	2.6	3.0	1.8	3.2	3.0	4.0	2.2	3.5	2.5	3.2
Asymmetric Cam	1.6	2.5	1.1	2.9	1.4	3.2	1.7	3.2	1.7	3.1	1.0	4.0	1.4	3.1	1.6	3.1
Signal Rectifying	1.5	2.8	1.7	3.1	1.6	3.2	1.7	3.2	1.4	3.2	1.0	4.0	1.2	3.3	1.6	3.1
Harmonic Vibration	2.4	4.1	1.9	3.7	2.6	4.1	2.4	4.0	1.6	3.9	3.0	5.0	1.7	4.0	2.2	4.0