Embedded System Based First-Year Engineering Course with Aid of Online Simulation and Social Media

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***Abstract* - Experiments and projects have been added to the curriculum in the Department of Electrical and Computer Engineering at a large southeastern university as part of a First-Year "Engineering Orientation" course. The goal is to enhance educational experience for engineering freshman with early introduction to research projects. In the course, students will gain introductory experience of hardware and software codesign with the focus on embedded system and robotics development. We used project-based learning to facilitate students' curiosities to explore the practical problems and challenges from the real-world for a deeper understanding on the cutting-edge knowledge in computer engineering. The students conducted 8 experiment-based collaborative works and two projects. Both the online simulator and real development boards are leveraged to validate those designs by the group of students. The online simulator provides students an integrated development environment, and realistic simulation with graphics. The experiments and projects developed online can be easily shared using social media such as Twitter, which made collaboration in groups very convenient in and outside the classroom. This paper will provide the implementation details of this course, and assessments of the students' work. We will discuss the feedback obtained from the class, and then explore for improvements and future plans.**

Index Terms – Embedded system, Project-based learning, Online simulation, Social media.

INTRODUCTION

A good engineer understands the fundamental mechanisms of the interacting complex phenomena behind significant engineering problems, and is capable of devising practical solutions accordingly. To this end, it is necessary for students to enjoy the learning process so that they may engage even more deeply in the learning process. As for the first year engineering students, it is necessary to create a learning environment that initiates, stimulates and perpetuates interest, creativity, motivation and an interest and desire in the students. Therefore significant changes required in both the theoretical and practical parts of a first year engineering introductory course.

Experiments and projects have been added to the curriculum in the Department of Electrical and Computer Engineering at a large southeastern university as part of a First-Year "Engineering Orientation" course. The goal is to enhance educational experience for engineering freshman with early introduction to research projects. In the course, students will gain introductory experience of hardware and software codesign with the focus on embedded system and robotics development.

During recent decades, project-based learning has shown to be an effective method that can improve engineering education significantly [1]-[6]. Project-based learning facilitates students' curiosities to explore the practical problems and challenges from the real-world for a deeper understanding on the cutting-edge knowledge in engineering. In particular, applying the project-based learning approach to courses in electrical and computer engineering curriculum can increase the challenge for students and their motivation levels [7, 8].

The students conducted 8 experiment-based collaborative works, including LED sequences, melody, and DC motor controls. We also developed two projects that incorporate various sensors based on these experiments. For example, students initialized their work on a temperature monitoring and cooling system project that resembles a closed loop system, followed by an advanced project to build an autonomous navigation robot.

Both the online simulator and real development boards such as Arduino and RoMeo microcontroller boards are leveraged to validate those designs by the group of students. The online simulator provides students an integrated development environment that includes electric components and microcontroller board, integrated development environment for programming, realistic simulation with graphics, and serial monitor for real-time communication. The experiments and projects developed online can be easily shared using social media such as Facebook and Twitter, which made collaboration in groups very convenient in and outside the classroom. Students can also conduct testing under various scenarios, or add different features to existing projects using the included duplicating projects function.

In the following sections, this paper will first discuss the layout of the course, and introduce to the hardware platform and software tool. Then we will explain the implementation methodologies, followed by the learning assessment and course evaluation, which leads to a conclusion of this paper.

LAYOUT OF THE COURSE

Project-Based Learning is incorporated in this course to facilitate students' curiosities to explore the practical problems and challenges from the real-world for a deeper understanding on the cutting-edge knowledge in electric and computer engineering. A quick pre-class survey shows that since the body of the class is first-year engineering students, the lack of experience on electronic devices, prototyping board, and especially programming is very common. Therefore, the course is design to start from fundamental of discrete components, and then move into microcontroller; from simple circuits to closed-loop systems. Table I gives the course schedule of the 16 weeks of the spring 2016 semester.

TABLE I
WEEKLY SCHEDULE OF THE COURSE

Week	Topic	Experiment
1	Course introduction and electric components	E1
2	Online simulator, circuit and connections	E2
3	Case study, microcontroller and Arduino	E3
4	IDE and programming	E4
5	LED and sequences	E5
6	Teamwork, brainstorming and discussion	
7	Functions, piezo and music player	E6
8	Intro to sensors [9, 10], and temperature sensor	E7
9	DC motor and step motor, potentiometer	E8
10	Spring break	
11	Control system, feedback and automated cooling	P1
12	system	
13	Scientific research and project management	P2
14	Robotics and autonomous systems, robot project	
15	Robot project (continued)	
16	Robot project (continued)	
	Project demonstration, presentation and discussion of future work	

The students conducted 8 experiment-based collaborative works, including electric components, circuit and connection, basic programming on Arduino, LED sequences, music player, sensors, DC motor controls and potentiometer. The schedule of these experiments from E1 to E8 can be found in Table I. Students can obtain skill sets in each of the experiment. For example, they learned connection of LED, structure of the program, repetition, analogWrite and digitalWrite functions in the experiment E5; Piezo elements, function prototypes and function calls in the experiment E6; Temperature sensor and conversion of sensor input in the program in the experiment E7; DC motor controls in the experiment E8. Then two projects P1 and P2 are developed based on these experiments. For example, in the project P1, students initialize their work on a temperature monitoring and cooling system project. In the project, an ambient temperature higher than the pre-set threshold value will create a temperature difference value, and trigger a sound alarm using the piezo element, a visual warning using the LEDs and also turn on the electric motor. The electric motor is equipped with fan, and the motor blows wind towards the sensor and heat source to cool them down. The speed of the fan changes with the temperature. The larger the temperature difference is, the faster the fan rotates. When the temperature of the sensor drops below the threshold, the alarm, LED and motor are all turned off. All necessary knowledge and skill sets are acquired by the students in their previous lectures and experiments, so they can work on this closed loop system, and then followed by an advanced project to build an autonomous navigation robot.

HARDWARE PLATFORM AND SOFTWARE TOOL

The two-wheel-drive robot is used in the autonomous navigation robot project. This robot platform is a small, low-cost chassis for use with a standard Arduino microcontroller. This kit features two differential DC geared motors which each drives a flexible rubber-tired wheel, and one rear caster wheel. This configuration gives the robot zero turning radius. It also features high-strength aluminum alloy frame with three sensor holders. The three sensor holders fit a variety of adjustable IR range sensors that can be used in this project, such as the Sharp GP2Y0A41SKOF infrared distance sensor.

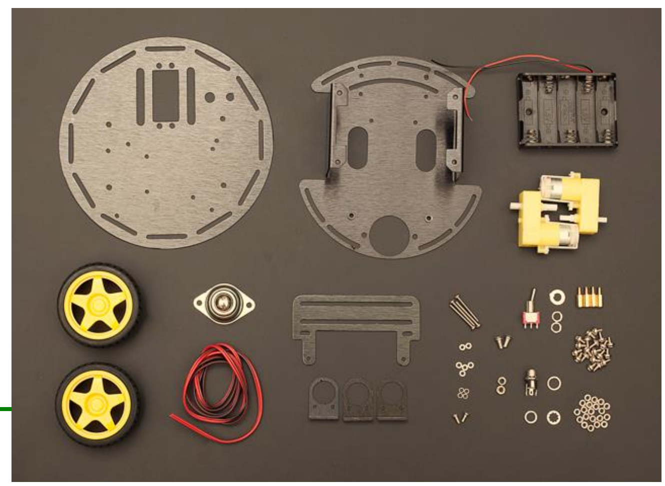

FIGURE 1
UNASSEMBLED TWO-WHEEL-DRIVE ROBOT SHOWING ALL PARTS.

RoMeo version 2 revision 3 microcontroller board is selected for this project. RoMeo is an all-in-one Arduino compatible microcontroller especially designed for robotics applications. The integrated two-way DC motor drivers allow students to start the project immediately without the need for any complex motor driver circuit on a prototype board. The board features DC output of 5V/ 3.3V, two-way motor driver with continuous output current up to 2A, and one stepper motor drive with 2A maximum current. It also has analog input on A0-A5, and A6 - A11 from digital pins 4, 6, 8, 9, 10, and 12; PWM output on 3, 5, 6, 9, 10, 11, and 13, which can provide 8-bit PWM output.

Arduino version 1.6.9, an open-source software is used as the integrated development environment (IDE). This IDE makes it easy to write the program and upload it to the board, and display serial data being sent to and from the Arduino board. This IDE runs on Windows, Mac OS X, and Linux.

The environment is written in Java and based on Processing and other open-source software.

IMPLEMENTATION METHODOLOGIES

The two-wheel-drive robot is used in the autonomous. A typical class of this course is demonstrated by the flow chat in Figure 2. The class starts with a short lecture focused on the topic and experiment. Students are then given the requirements of the experiment. They work in groups of four to design and validate the experiment. Online simulation is used in this phase. The online simulator provides real-time simulations result, and also gives animation if there is any error. For example, if the current of a LED is not restricted by an appropriate resistor, an explosive symbol will be displayed on that LED to warn the user. Therefore, the group of students can come back to modify the design. This step avoids the hazard such as short circuit on a real experiment board, and encourage every students to work on their designs freely.

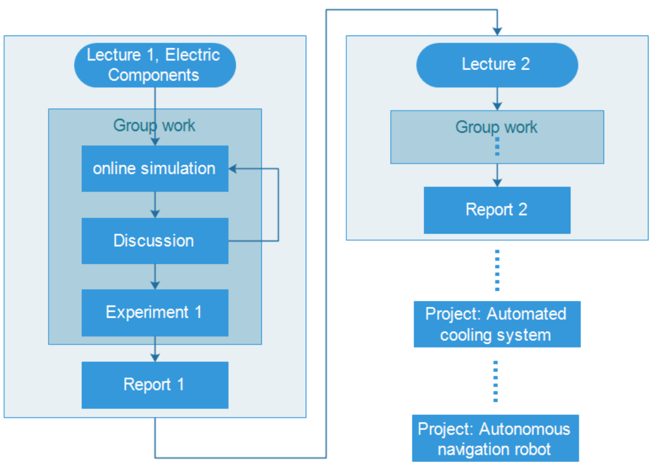

FIGURE 2
FLOW CHAT OF THE COURSE SCHEDULE

In the project, for example, the project P2-autonomous navigation robot, a video demo of the final objective is played at the beginning of the class. Students started to break down the project into milestones: robot, microcontroller, programing, and testing. They share and discuss their opinions so that everyone could begin to learn how to approach these problems at an early stage. The milestones were then further divided into a series of small modules. For example, in programming, one module consists of functions for movements, readings from distance sensors, communication with the computer, and object avoidance. Students solved these problems together: one student started by recognizing and prioritizing the problems, and passing it to the next student, who gathers relevant information and makes assumptions, and the next student, who filled in variables and conditions, then the next student interpret the data, and put the robot to test, and so forth until the problem that students originally did not understand was solved.

Two undergraduate learning assistants attend every class to help the instructor provide classroom coverage to facilitate instruction.

The online simulator is leveraged to validate experiment designs by the group of students. The online simulator runs in the web browser and offers a number of electronic components, integrated circuits and instruments, as well as a large collection of pre-made designs. Students can drag and drop components from a large library of electronic components, integrated circuits and instruments. It supports Arduino programming using a built-in code editor. Student can 'run' the simulator to validate the design.

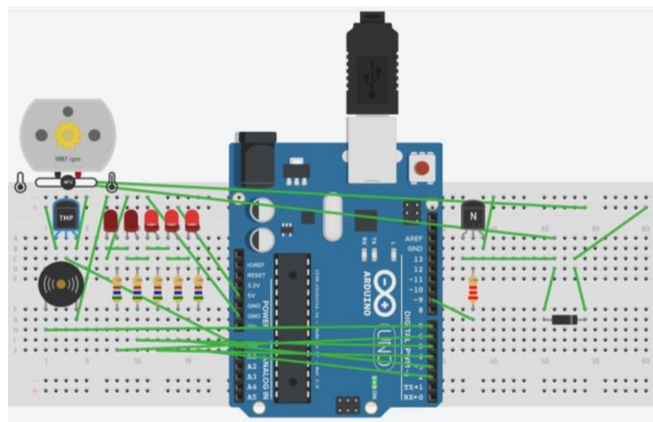

FIGURE 3
SIMULATION OF THE TEMPERATURE MONITORING AND COOLING SYSTEM.

FIGURE 4
DESIGNS FROM THE ONLINE SIMULATOR ARE SHARED ON TWITTER.

For example, Figure 3 shows the design of the aforementioned project P1, temperature monitoring and cooling system. When the simulated system is running, the simulated ambient temperature can be adjusted using the slide bar above the temperature sensor on the left side of the prototype board. A high temperature will turn on the LEDs, trigger the sound alarm which can be heard from the speakers of the computer. And the real-time rpm is displayed on the DC motor.

The experiments and projects developed online can be easily shared using social media such as Twitter, as shown in Figure 4. This makes collaboration in groups very convenient in and outside the classroom. Students can also conduct testing under various scenarios, or add different features to existing projects using the included duplicating projects function.

LEARNING ASSESSMENT

Students' learning are assessed using project demonstrations combined with traditional experiment reports. The former check the students' work on open-ended tasks, while the later reinforce the fundamentals of this course.

I. Experiment Report

An experiment report is assigned after each experiment. For example, in experiment E8, how is the transistor used as an electronic switch is explained in the lecture. In their report, students are asked to answer the following questions based on their research and observation from the experiment.

- What is a transistor? Explain the function of the transistor put in the circuit?
- Why the diode is called a "flyback diode"?
- Explain the structure of your program. How does your program achieve each of the functions?
- How to make the system work better?

II. Project Demonstration

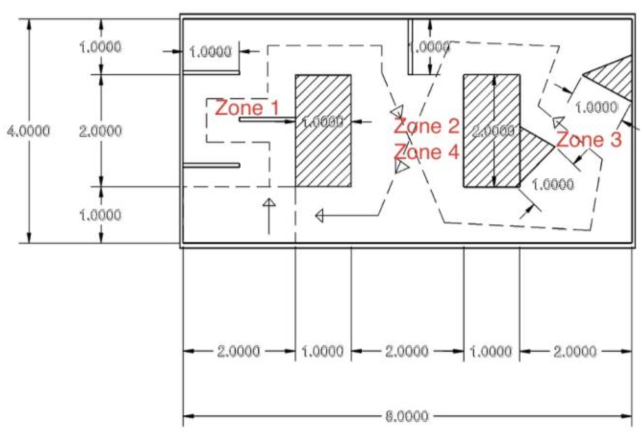

FIGURE 5
LAYOUT OF THE TRACK FOR AUTONOMOUS NAVIGATION ROBOT PROJECT.

In the project demonstration of the autonomous navigation robot, the robot should complete a tour in a closed track with obstacles in minimum time. Before the demonstration, a training track is available to students for practice purposes. Student groups are allowed to use some customized parts such as different wheels, but restrictions such as battery voltage are set. Figure 5 shows the layout of the track. The track consists of four different zones.

One point will be deducted for every time a robot touches or bumps into a wall in each zone, but there will be no negative points. If a robot becomes stuck on a wall, or travels in the backward direction on the track for more than 5 seconds, the robot will be allowed one reset to the start line of the track with a new time, and 5 points will be deducted for the section. Table II gives the scoring schedule.

TABLE II
SCORING SCHEDULE OF THE DEMONSTRATION

Item	Scoring Schedule	Points
A	Time to complete course	20
B	Obstacle Avoidance zone 1	20
C	Moving Obstacle Avoidance zone 2	20
D	Obstacle Avoidance zone 3	20
E	Drunk driving simulation Obstacle Avoidance zone 4	20

COURSE EVALUATION

Based on the statistics of the attendance in the class, the attendance of this first year engineering course is greatly improved. The in-class discussion improves effectiveness and performance, especially in teamwork and projects. Increased conceptual understanding of lectures are also achieved, which is reflected by the deeper analysis and more comprehensive understanding of the concepts in the experiment reports.

TABLE IV
RESULTS OF POST PROJECT SURVEY

Survey Question	Sp2016	Sp2014
Use basic engineering principles to analyze the performance of processes and system	4.9	4.1
Interpret results of an experiment	4.8	3.1
Apply systematic design procedures to open-ended problems	4.8	3.5
Work in teams where knowledge from many engineering disciplines must be applied	4.5	4.4
Test potential solutions to an engineering problem	4.7	3.6
Use feedback from an experiment to improve solutions to an engineering problem	4.8	3.2

Moreover, post project surveys are made to collect data explicitly for the hands-on experiments and projects. Table IV shows the survey questions and the score comparisons of Spring 2016 class and Spring 2014 class. The survey is in a scale of 1-5. 1 is strong disagree, and 5 is strongly agree. Survey outcomes highlighted the contribution of these hands-on components to analyzing problems, designing systems, interpreting data, and generating solutions to engineering problems. One student's statement says 'although the project was challenging. I enjoyed working on it. It was also great working on the board, which allowed me to get a hands-on fell of being an engineer.' Figure 6 shows a student group's autonomous robot navigates through the track.

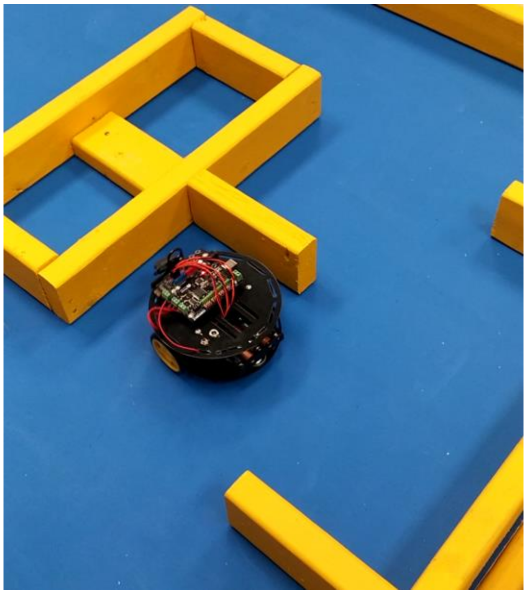

FIGURE 6
A ROBOT NAVIGATES THROUGH THE TRACK.

CONCLUSION

The paper focuses on the effort to motivate first year students in electrical and computer engineering. The teaching methods combine traditional teaching, such as lectures with interactive design experiments and open-ended projects. The students work collaboratively, gaining not only a much better conceptual understanding of the course contents, but also a unique and valuable hand-on experience in their first year before advancing into the engineering curriculum. The online simulator and social media made the collaboration in groups very convenient in and outside the classroom. Survey outcomes highlighted the contribution to the students' ability of analyzing problems, designing systems, interpreting data, and generating solutions to engineering problems.

The approach of project-based learning, new tools, social media, and assessment will be applied on the future offerings of first year engineering courses. It will be interesting to compare ongoing results to check the validity of this approach. However, with the additional experiments and projects to the lectures, the workload for both students and instructors is much higher. Therefore, time management and control of reasonable workloads will be interesting topics for future teaching of this course. Coupled with 3D objects detection algorithms [11, 12], the project can be extended to a more challenging vision-based autonomous driving robot project in the future course.

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Nansong Wu received M.S. and Ph.D. degrees in Electrical and Computer Engineering from Florida International University, Miami, FL, USA, in 2008 and 2012. He is a faculty member with the Department of Electrical and Computer Engineering, Florida International University. His research interests include high-performance embedded systems, image processing, wireless communication, and IoT applications. He is interested in engineering education, and he has successfully applied project-based learning approach in several engineering courses.