Arduino to the Rescue: Swaying Undecided Freshmen Engineering Students to Electrical and Computer Engineering

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Abstract

We describe the implementation and outcomes of the Arduino based electrical engineering and computer engineering (EECE) module, which is integrated within the "Engineering Discovery 1" course taken by all computer, electrical and mechanical engineering freshmen at Marquette University. Because a significant number of students enrolled in this course have not yet chosen a specific engineering major, one of the goals of the EECE module is to provide experiential learning activities designed to be engaging and fun while presenting important electrical and computer engineering concepts to attract and motivate undecided students to select electrical or computer engineering as their major. In addition, these activities are intended to retain those students who have already declared an electrical or computer engineering major as well as to give them a taste of what's to come. Data and student feedback indicate that the new EECE module was received very positively as it stirred increased interest into EECE and motivated students to be proactive. In the future, we plan to double the duration of the module and thus expand it to cover an even larger spectrum of EECE topics.

Keywords

Freshmen engineering; Experiential learning; Project-based teaching; Engineering major selection.

Introduction

Two of the most important decisions that a first-year engineering student will make during the first few months are whether to continue to pursue a degree in engineering in general and what field of engineering study to pursue. Although some students enter the first year with a departmental major already in mind, many freshmen students have not declared their major yet. These students represent about 28% of the freshmen student population[1]. In addition, a significant fraction of the freshmen students quit or change to a non-engineering major after the first year in college. The typical retention rate by the end of the first year among all freshmen engineering students is about 70-80%. Generally, this is in part the reason for relatively low graduation rates too. For example, in 2013, the graduation rate for full time students attending a four-year university and graduating within six years was only 59%[2]. These numbers are significantly better however in the case of private schools like the authors' institution. For example, the Office of Institutional Research and Analysis (OIRA) data at Marquette University indicate a percentage of 19% of freshmen engineering students with an undeclared major in Fall 2015 and a graduation rate in four years of 89% in Spring 2015 among all students in the College of Engineering.

Consequently, it is extremely important that the courses that these students take in the first semester are designed to meet two primary objectives: 1) Provide engaging and fun yet challenging learning experiences such that students become more interested in engineering and motivated to stay in engineering fields. 2) Expose students to various aspects of engineering design from different fields to help them make an informed decision about what major. For example, it has been observed that general engineering courses in the freshmen year help students make early informed decisions about their major and that those students graduate approximately 10% sooner than other engineering students[3] Moreover, programs focused on "the first year experience" may have a positive impact on the overall graduation rates[4].

"Engineering Discovery 1" is a course taken by all computer, electrical and mechanical engineering freshmen at Marquette University, where the content of the course is designed and intended to achieve each of the above primary objectives. The course includes a one week electrical engineering and computer engineering (EECE) module. The focus of this paper is the EECE module (for which we are the co-instructors), which has been completely redesigned to modernize and align its activities to more current topics.

Premises Underlying the Design of the EECE Module

The EECE module is one week long and includes one 50 minute lecture and two laboratory sessions of two hours each. The purpose of this module is to introduce freshmen students to the field of electrical and computer engineering through the use of a hands-on laboratory experience which is chosen to introduce students to EECE concepts. We want this first time exposure to EECE concepts to be engaging, challenging, and to foster or nurture curiosity about electrical and computer engineering. The two goals we set for the EECE module are that first, a higher percentage of undecided students choose an EE or CE major and second, students who have already chosen EECE remain committed. In addition to the above goals, in designing the content of the EECE module, we needed to address another challenge. We wanted to teach interesting and potentially helpful topics to the freshmen students in the course who are majoring in mechanical or civil engineering.

One of the most promising teaching approaches has been shown to be the project-based learning[5]. Therefore, we decided to adopt in-class project-based learning in both laboratory sessions. Project-based learning emphasizes activities that are long-term, interdisciplinary, and student-centered. It has numerous benefits, including a greater depth of understanding of concepts, improved communication and interpersonal/social skills, enhanced leadership skills, increased creativity, and improved writing skills[6]. To foster a self-learning attitude, students are required to study assigned materials and are encouraged to seek information on their own in preparation for the online quizzes they can take before each of the lab sessions.

Note that our approach aligns perfectly with what the electrical and computer engineering department heads association (ECEDHA) has featured as a successful solution to the problem of low freshman retention rates in electrical and computer engineering[7].

Description of the New EECE Module

To address the challenges and achieve the goals described in the previous sections, we decided to build the module activities around several laboratory experiments that use the Arduino board. In this way, while using a microcontroller board that is current, we also tap into vast amounts of online resources that exist due to the popularity of the Arduino platform. Using the Arduino platform in a general engineering course is not new. For example, the study by Recktenwald and Hall[8] reports the implementation of an entire semester long course that uses the Arduino platform. However, in our case we are restricted to only one week to present EECE concepts and this makes our task quite challenging.

The experiments start with simple projects that use light emitting diode (LEDs) and 7-segment LED displays to introduce the Arduino development environment and culminate with a more complex project that implements a complete data acquisition system to measure temperature and humidity. This type of system resonates with mechanical and civil engineers who often find themselves monitoring, for example, engines or other mechanical systems, buildings, bridges, etc. In addition, the Arduino based platform facilitates teaching of concepts from both electrical and computer engineering disciplines. This approach has been used with positive results in other schools[8,9] . We provide more details of these activities in the following sections.

Phase 1: Introduction to Microcontrollers

In this section we describe the activities that form the first major part of the EECE module. This part includes the 50 minute lecture and the first two hour laboratory session.

The focus of the lecture is to introduce students to several main topics, including microcontrollers, data acquisition, and control theory. Basically, the lecture builds on the general concept of a closed control loop, formed by a plant that is monitored by various sensors, a control technique which makes use of the sensor data, and actuators that close the loop. A generic control system diagram is utilized as a testbed for discussing examples from power systems, automotive engines, buildings and bridges, and microcontrollers. Data acquisition is specifically discussed as the process of collecting readings from various types of sensors including temperature, humidity, vibration, etc. Thus, we create the entire lecture on the concepts of control and system monitoring that can be identified in virtually all engineering disciplines. A particular emphasis is placed on electrical and computer engineering aspects through the introduction of the Arduino board, which is used in the laboratory activities.

Arduino is an open-source electronics platform based on easy-to-use hardware and software[10]. An Arduino Uno board (see Fig.1) consists of an 8-bit Atmel AVR microcontroller with complementary components to facilitate programming and incorporation into other circuits. The board has a USB plug to connect to a host computer and a number of connection sockets which can be wired up to external electronics, such as motors, relays, light sensors, laser diodes, loudspeakers, microphones, etc. The board can be powered through the USB connection from the computer or from a 9V battery. Arduino has become one of the most popular microcontroller boards, used both by hobbyists and in educational environments. One can find significant amounts of educational materials, example projects, and other online support. Many introductory level books as well as more advanced books about Arduino programming are available[11].

Figure 1: The hugely popular Arduino Uno board is used as the microcontroller platform of choice in the EECE module.

The goal of the first laboratory session is to have students become familiar with the Arduino development environment (IDE) by creating three different projects:

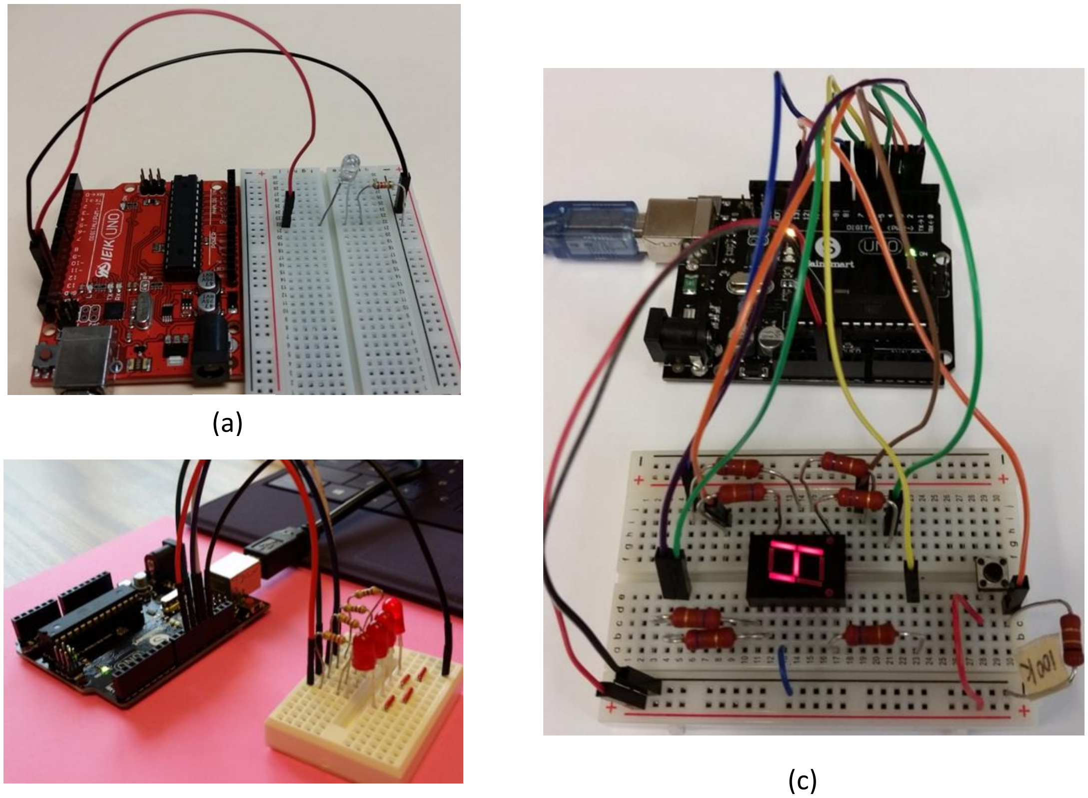
- Blink LED
- Lighting effects using an array of four LEDs
- Electronic die using 7-segment LED display

These projects are complete examples that involve both hardware and software and are adapted from some of the projects discussed in Simon Monk's book[12]. The experimental setups of each of these three projects are shown in Fig.2 on the next page.

In the first project, an LED is turned on and off repeatedly. In the second project, a set of four LEDs is controlled to create a lighting pattern, e.g., one LED is on at a time and controlled in a moving pattern from left to right in the array. In the third project, students implement an electronic die, which generates a random number between 1 and 6 as a response to pressing a push button and displays the number on a 7-segment LED display.

These projects allow students to become familiar with the use of the Arduino IDE to program the microcontroller and to write simple programs that need to be compiled and downloaded onto the board. In addition, these projects expose students to simple hardware prototyping as they must wire the Arduino board, resistors, LEDs, push buttons, etc. to construct circuits on an experimenter's breadboard. In addition to these cool aspects, the projects cover basics of programming (such as variable declarations and while statements), random numbers, and electronic circuits while facilitating creativity. For example, students can change the program to control the four LED array in any way they want. Furthermore, students are required to read and search for specific information in datasheets.

By the end of the first laboratory session, students should be familiar with many of the aspects of using an Arduino board and the Arduino IDE.



(a) (b) (c)

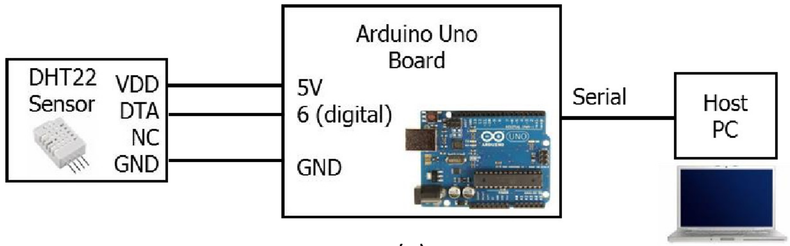
Figure 2: (a) Experimental setup of the *blink LED* project. (b) Experimental setup of the *lighting effects with four LEDs array* project. (c) Experimental setup of the *electronic die on 7-segment LED display* project.

Phase 2: Data Acquisition Systems for Temperature and Humidity Monitoring

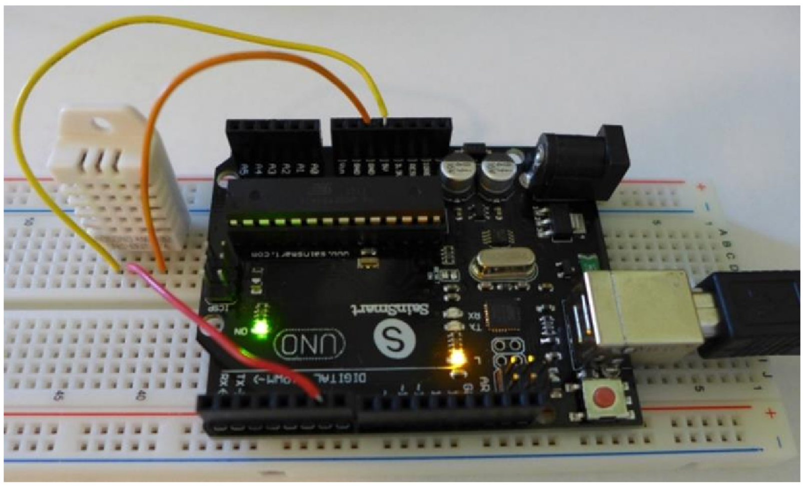
In the second two hour lab session, students build a data acquisition system using a DHT22 humidity and temperature sensor and the Arduino Uno board connected to a host PC. The schematic diagram and experimental setup of this project are shown in Fig.3. The DHT22 sensor is connected to the Arduino board to provide humidity and temperature values as measurement data. The data are read in by the Arduino board, which passes them to the host PC via the serial port. On the host PC, the data can be saved in a file or it can be plotted as a graph in Excel, etc.

The DHT22 sensor, also known as the RHT03, is a humidity and temperature sensor[12]. The sensor is already calibrated and does not require extra components. Hence, it can be used directly to measure relative humidity and temperature.

To communicate with the DHT22 sensor, we use an open source Arduino library[13]. Between the first and second lab sessions students are required to download and install this library. By using functions defined in the library in the program executed by the microcontroller, students are able to easily retrieve the humidity and temperature data from the sensor. In this way, we introduce students to the concept of libraries that can be used in programming in order to speed-up the process of software development.



(a)



(b)

Figure 3: (a) Block diagram of the *data acquisition* project. (b) Experimental setup.

Discussion and Future Work

We implemented this new EECE module in the Fall 2015 semester. To measure the impact of the new EECE module, we compared the numbers of students with declared majors as CE and EE at the beginning and at the end of the Fall 2014 and 2015 semesters. In the case of the Fall 2014 semester, the number of declared CE majors declined by 12% while the number of declared EE majors increased by 6.25%. In contrast, in the case of Fall 2015 semester, the number of declared CE majors increased by 20% while the number of declared EE majors remained unchanged. This shows that some students who were undecided at the beginning of the Fall 2015 semester decided to select computer engineering as their major by the end of the semester. We attribute this very positive change for the computer engineering major to the new EECE module.

Furthermore, student feedback on the EECE module through the course evaluations at the end of the semester were very positive. Consequently, the instructor of the course has asked us to expand the EECE module to two weeks. This expansion will allow us to cover a larger number of concepts through project-based activities created with Arduino boards, and thus we will be able to make even a stronger case for the electrical and computer engineering field of study. Finally, all the documentation materials and source codes created as part of this module have been made publicly available[14].

Conclusion

Having as primary objective to attract and motivate undecided freshmen engineering students to select electrical or computer engineering as their major, we have created a new electrical engineering and computer engineering module. This module was integrated within the "Engineering Discovery 1" course taken by all computer, electrical and mechanical engineering freshmen at Marquette University. The EECE module, created around Arduino based projects, was designed to provide experiential learning that is engaging and fun while presenting important electrical and computer engineering concepts. Data and student feedback indicate that the new EECE module was received very positively as it stirred increased interest into EECE and motivated students to be more curious and proactive. Encouraged by these results, we plan to double the duration of the module and thus expand it to cover an even larger number of EECE topics.

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