AC 2011-20: TRANSFORMATIVE LEARNING EXPERIENCE FOR INCOMING FRESHMEN ENGINEERING STUDENTS THROUGH ROBOTICS RESEARCH

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Transformative Learning Experience for Incoming Freshmen Engineering Students through Robotics Research

***Abstract* – An intensive four-week 2010 Summer Bridge pilot program introducing four incoming freshmen to robotics research is presented in this paper. Through this program, students acquire the necessary knowledge and skills to become active participants in an ongoing robotics research project their first semester at the university. Through a sequence of focused learning modules, each consisting of a lecture presentation followed immediately by correlated hands-on activities, students learn essential concepts, and develop basic laboratory skills in electrical engineering and microcontroller programming. After establishing the foundational knowledge, the students are given a carefully circumscribed embedded system design problem, and guided to a solution integrating the hardware and software introduced in the course. All students completed the program, delivering their final project, and have remained involved in the ongoing robotics research activities during their freshman year at the university. This paper presents the course structure and content, hardware and software utilized, and the final project.**

INTRODUCTION

A large body of research has accumulated showing the benefits of hands-on activities in promoting learning in science courses relative to the traditional lecture-only approach at the elementary, middle and high school level [1][2][3][4]. Studies at the university level have also suggested improved learning outcomes in engineering courses when hands-on activities are a part of the lesson plan [5][6]. Moreover, these outcomes are in agreement with what current theories of learning would predict [7]. Project-based learning involving hands-on activities has been introduced into engineering courses to improve student motivation and engagement. A challenge has been to identify projects at the freshman level that introduce content relevant to the engineering curriculum and yet is within the capability of students with no previous engineering coursework. One approach to project-based learning has been in the area of robotics, which requires minimal preparation before students are capable of performing hands-on activities [8]. Project-based learning centered on robotics has also been used as a foundation to introduce topics in related engineering content areas [9].

Hands-on activities have also been introduced into freshman undergraduate engineering courses

The Summer Bridge program is distinguished from other project-based, hands-on engineering courses in that, rather than using a project as a teaching tool in a course whose primary objective is to prepare students for future coursework, it is designed to provide an avenue for incoming freshman with STEM (Science, Technology, Engineering and Mathematics) majors to become involved in research early in their academic career. The students must apply and be accepted into a research group of their choice. The research group targeted by the Summer Bridge class presented in this paper prepares the students to become active participants of the Automated Underwater Vehicle (AUV) design group. The mission statement for this group is to build a remote-controlled robot for performing various visual and acoustic tasks, and, in particular, to complete the mission challenge of the Association for Unmanned Vehicle Systems International (AUVSI) Underwater Competition. AUVSI is a non-profit international group dedicated to advancing the technology of unmanned vehicles. The Underwater Competition is an annual student competition sponsored by AUVSI. This research project is divided into several subprojects and areas as illustrated by the organizational chart in Figure 1.

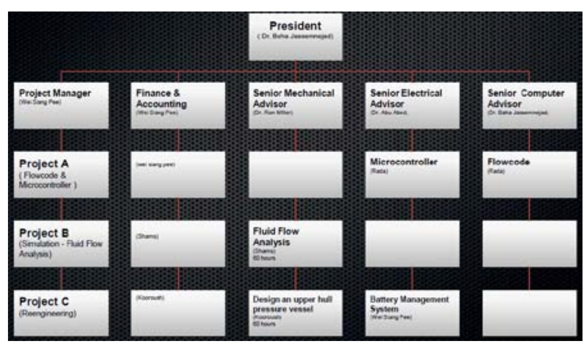

FIGURE 1.
UAV PROJECT ORGANIZATIONAL CHART

Another challenging aspect of the 2010 Summer Bridge program was the selection of embedded microcontroller design as the organizing content area for the project. This choice was made in order to include a greater breadth of engineering content. A *microcontroller* is a computer on a single integrated circuit, such as the ATMEGA32 microcontroller from Atmel used by the students in the Summer

Bridge program (Figure 2). The microcontroller is the heart of a control system. An *embedded* microcontroller is programmed to perform a limited set of functions as a permanent part in a particular system. For example, a microcontroller is used to control the operation of a microwave oven. The inputs provided by the keyboard are used by the microcontroller to set the cooking time and power level. This embedded microcontroller is considered a permanent part of the microwave, and its function will never be reprogrammed for any other purpose.

FIGURE 2.
ATMEGA32 MICROCONTROLLER

The aim of the 2010 Summer Bridge was to develop the skills necessary for the students to become active participants in the embedded microcontroller system design for the AUV project. The embedded microcontroller system in the AUV project will be used to monitor the physical environment of the AUV, the status of its electronics, as well as control its movement. To accomplish this aim in four weeks, the selection, sequencing, and method of presentation of topics, had to be carefully considered. Designing such a system requires the development of specific knowledge and skills in the areas of electronic circuits, microcontrollers, and programming. The remainder of this paper presents the course methodology used to achieve this aim.

METHODS

Embedded microcontroller system design involves several relatively distinct engineering content areas: electronics, digital systems, and programming. In the Summer Bridge course, students are presented with the essential concepts in these areas through a sequence of focused learning modules, each consisting of a lecture presentation followed immediately by correlated hands-on activities that allow students to test their understanding of the content presented in the lectures. In the course of performing the activities, the students also acquire basic laboratory skills, such as use of a multimeter to take voltage and resistance measurements, and soldering on a printed-circuit board. As the students acquire the necessary concepts and skills, they begin constructing the components of an embedded microcontroller system, presented as a series of mini-projects. The mini-projects reinforce the knowledge base that has been developed, plus introduce the concept of building a complex system from simpler subsystems. The final project requires the students to work as a group in meeting a design challenge which implements their completed microcontroller system, forcing the students to develop their empirical reasoning and communicative learning ability.

The students met for the course during the afternoon, from 1:00 pm to 5:00 pm, four days a week, over a four-week period, in a fully-equipped teaching laboratory where students had access to all of the required laboratory equipment and supplies. Each afternoon session began with a presentation over the key concepts for that session, followed by laboratory exercises designed to reinforce the concepts presented in the lecture. The students were assisted by the Electronics Associate for the department and two advanced undergraduate students involved with the AUV project.

The first two weeks were dedicated to laying the conceptual foundations in the electronics and digital systems content areas, and building the components of the embedded controller system. During the third week, the students learned to program the microcontroller, and began their final project. The project was completed, and the students prepared their final project report and presentation. The presentation was given during the final class session. A more detailed schedule is provided in Figure 3.

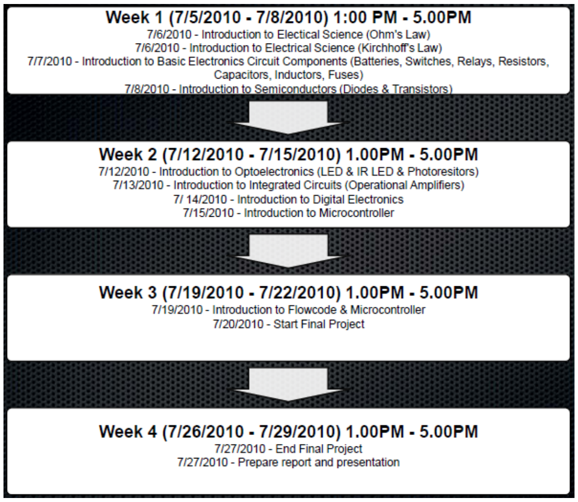

FIGURE 3.
TOPIC PRESENTATION SCHEDULE

The laboratory portion of each session on electronics involved the following five elements:

- Introducing new electronic components
- Wiring a circuit on the breadboard
- Taking measurements with a digital multimeter
- Verifying a principle presented during lecture using the experimental measurements
- Performing a simulation of the circuit on the computer

Circuit simulation requires the student to construct a schematic using the simulation software, developing their familiarity with this abstract representation of a circuit and its relationship to the actual circuit. For this purpose, the circuit simulation program Multisim™ from National Instruments was used (Figure 4). The interface is easy for the students

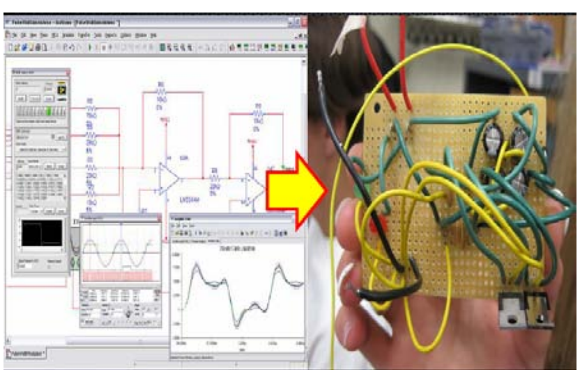

FIGURE 4.
MULTISIM CIRCUIT SIMULATION SOFTWARE

to understand. Schematic symbols for components and meters are dragged onto the diagram from a menu using the mouse, and component are connected by clicking on the pairs of terminals to be joined. Clicking on the "Run" button simulates the circuit, displaying the resulting simulated voltage values on the associated meter icons.

The ATMEGA32 microcontroller from Atmel was selected for this program due to its ease of use. It can be programmed through the USB port of a computer running Windows (Figure 5).

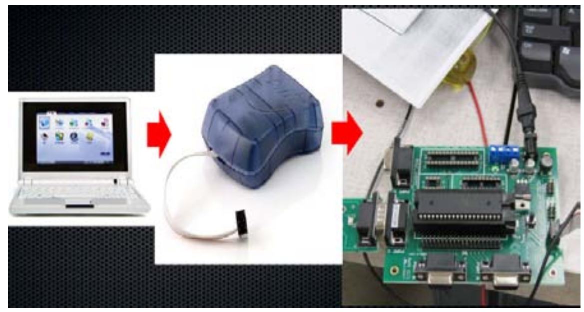

FIGURE 5.
HARDWARE CONNECTIONS FOR PROGRAMMING THE ATMEGA32 MICROCONTROLLER

The microcontroller is programmed using the graphical programming interface FlowCode™ from Matrix Multimedia (Figure 6) which introduces the students to programming structures through use of flowcharts.

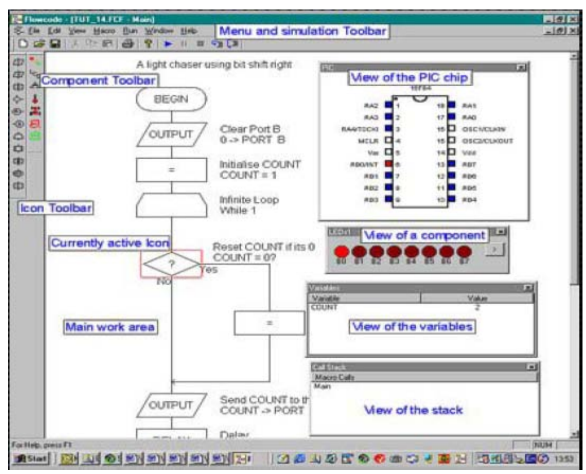

FIGURE 6.
FLOWCODE INTERFACE

The students construct the subsystems of their microcontroller system as a sequence of four mini-projects on separate printed circuit boards (Figure 7):

- Power Supply Board
- Switch Board
- Microcontroller Board
- LED Board

This develops in the student the habit of seeing a system as being comprised of a number of blocks, and to verify the function of each block independently before they are connected together.

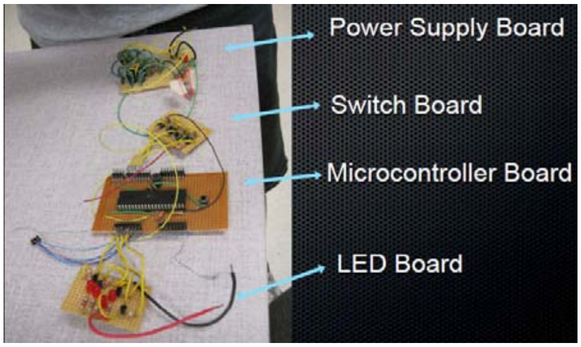

FIGURE 7.
SUBSYSTEM BOARDS

Only after verifying that each subsystem board is working correctly, are the students allowed to wire the boards together to form the completed microcontroller system. The students are given two simple design assignments that involve turning the LEDs on and off in a timed sequence controlled by different switch settings. The FlowCode software permits simulation of the student-written programs, using mouse-operated switch symbols and graphical LED icons, before downloading the program to the board. This allows them to localize any problems they have to either their program or the hardware.

The final project is an LED-sequencing display in which the students design and implement their own LED pattern and sequencing. The use of power transistors was discussed at this point as they were necessary to drive the large number of LEDs controlled by the microcontroller outputs. These can be seen on the breadboard in back of the LED display (Figure 8). The front of the completed LED display, which shows “UCO AUV”, is shown in Figure 9.

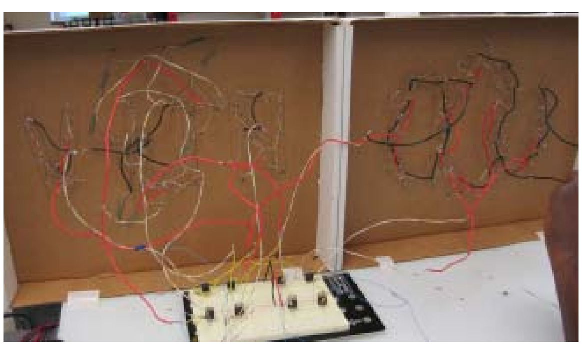

FIGURE 8.
BACK-VIEW OF LED DISPLAY

The students prepared a report on their project, and a presentation that they made during the final session, further developing their communication skills.

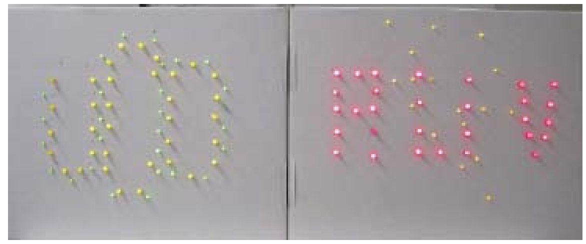

FIGURE 9.
FRONT-VIEW OF LED DISPLAY

RESULTS

One challenge in the design of this course was to determine the content necessary to achieve its aim. The course content in electronics delivered during the first two weeks was bare bones but sufficient. In retrospect, an additional week to focus on microcontroller architecture would be desirable, but not essential.

The matrix organizational chart proved to be an effective tool in clearly describing the AUV project to the students and the purpose of their training. Such charts are being used more frequently in businesses where new products, customer groups, and technology, are introduced on a regular basis. This is especially true in the environment of academe, with its plethora of evolving research topics and subsequent student projects, often requiring the most current technology available.

Another aspect of real-world project management is the development of a vision statement and a mission statement. The vision statement addresses long term objectives, while the mission statement concerns more short-term goals. The vision statement for the AUV project, “To be the nation’s leader in underwater robot research and development”, is satisfactory. The mission statement, however, requires some further development. One critical area not discussed in the mission statement and needful of consideration concerns the viability of the project: the prospects for the project to survive long enough to complete its mission. From the perspective of the AUV project, student training can be considered one of the deliverables, with the student trainees as customers. Once students become group members working on the project (employees), they should be utilized in training new students. Unfortunately, the current funding level for the project ($1000) is not sufficient to adequately compensate the required employees.

An increased funding level is the most glaring need of the project at this point in time.

The aim of the course, to prepare incoming freshmen for participation in robotics research, was satisfied. The students completed all activities, including the final project. All four have continued as majors in the engineering program, and are currently involved in the AUV research project.

CONCLUSION

A Summer Bridge program introducing four incoming freshmen to robotics research is presented in this paper. Through this program, students acquire the necessary knowledge and skills to become active participants in an ongoing robotics research project their first semester at the university. A novel aspect of this approach is the change in the perspective it provides to the students. Rather than seeing themselves only as recipients of knowledge, they come to see themselves as active participants in a community of engineers, which is, after all, the presumed objective of their education. Rather than waiting until graduation to make this transition, the students begin this change in self-perception from the beginning of their freshman year.

Through a sequence of focused learning modules, each consisting of a lecture presentation followed immediately by correlated hands-on activities, students learn essential concepts, and develop basic laboratory skills in electrical engineering and microcontroller programming. The students apply the concepts presented to construct an embedded microcontroller system. The students are then given a carefully circumscribed embedded system design problem, and guided to a solution integrating the hardware and software introduced in the course.

The strong emphasis on hands-on activities in the course, and especially the group projects, encourages *instrumental learning*, in which truth is established through experiment, and *communicative learning*, which involves two or more individuals working to reach a consensus of understanding through discourse that examines the evidence, arguments, and considers all points of view. More generally, involvement in these types of learning modalities helps students to become more proficient at critical reflection on the assumptions made in consideration of any given subject, a necessary pre-requisite to a transformation of a frame of reference, i.e., transformative learning. [10].

Two weeks of instruction on basic electronics proved to be satisfactory, however an additional week would have been desirable to cover some aspects of microcontroller architecture. The course required a large time commitment from an Electronics Associate working for the department, and two upper-level students. The most pressing need currently is to obtain sufficient funding for the course assistants.

All students completed the program, delivering their final project, and have remained involved in the ongoing robotics research activities during their freshman year at the university. Since the aim of the program was achieved, the program was judged to be a success.

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