AC 2012-3896: A TRANSFORMATIVE LEARNING EXPERIENCE: UNDERWATER ROBOTICS RESEARCH

Prof. Baha Jassemnejad, University of Central Oklahoma

Baha Jassemnejad is Chair and professor of engineering and physics.

Mr. Wei Siang Pee, University of Central Oklahoma
Mr. Kevin Rada, University of Central Oklahoma

Engineering & Physics Department, Edmond Okla.

Mr. Devon Kelley Keith, University of Central Oklahoma

Mechanical and Electrical Systems

Mr. Dylan Bradley Miller
Dr. Evan C. Lemley, University of Central Oklahoma
Adam Dorety, University of Central Oklahoma

Adam Dorety is currently a freshman at the University of Central Oklahoma (UCO). He is involved in UCO Robotics, and the UCO chapter of the American Society of Mechanical Engineers. He has continued his research on the Underwater Remote Operated Vehicle (ROV) and hopes to compete at the national tournament in June 2013. He hopes to graduate in 2015 and join the workforce. His experience with undergraduate research has undoubtedly strengthened his commitment to mechanical engineering.

A Transformative Learning Experience: Underwater Robotics Research

Abstract – **This paper discusses a transformative learning experience that was provided in the summer of 2011. The freshmen of the Robotics Engineering Group in the Summer Bridge 2011 Program designed and built an underwater ROV (remotely-operated vehicle) to perform underwater exploration of, for example, local ponds and lakes. The duration for the project was four weeks in July and the first part of the Fall semester. The students were given instruction in the basic electrical and mechanical principles associated with the project, and introduced to a set of components that would be available in the completion of the project, through a sequence learning activities that included lectures and laboratory exercises. Students were also given instruction on the engineering design process paradigm. The separate elements of the course were integrated as the students designed, constructed, tested, and modified a prototype ROV.**

INTRODUCTION

The Summer Bridge program is designed for incoming freshmen with STEM (Science, Technology, Engineering and Mathematics) majors who desire an educational approach that emphasizes learning through participation in research and engineering activities in their field of study. The students must apply for, and be accepted into, a research group that most interests them. Students in the research group are then given a project assignment, and provided with the necessary knowledge (principles, tools, and techniques) to complete the project. The project assignment is constrained by the allotted completion time. The time required to present the additional knowledge required, to allow students to experiment with the new knowledge so it is internalized, and finally consider how the knowledge can be utilized in the completion of the project, must be considered. Defining a project that satisfies these constraints is challenging aspect in the design of a transformative learning experience.

The long-term goal of the research group discussed in this paper is the design of an underwater remotely-operated vehicle (ROV). This research group, presently in the initial stages of development, will eventually involve students at all academic levels. The knowledge and skills required to complete such a project will become more extensive as the research group develops, eventually incorporating many of the concepts and techniques learned by the students in the engineering curriculum. Students at each academic level will be assigned design challenges compatible with their background. A program is envisioned in which students will continue with the research project throughout their academic career, applying the knowledge acquired through their coursework to an increasingly complex sequence of design challenges.

This paper describes the experiences of the first freshman group involved in the ROV research. These students are the pioneers in this group, and as such had to produce a complete ROV, which future groups will improve upon, with minimal engineering ability assumed. In the 4-week Summer Bridge program, a basic set of concepts to be introduced was determined, and a basic ROV kit was selected for the students to complete. The basic physical concepts introduced were on buoyancy, and electric circuit principles. The students were introduced to an assortment of basic electronic components (resistors, capacitors, switches, diodes, LEDs, transistors, integrated circuits such as voltage regulators and digital ICs), some of which would be utilized in the present kit and others which would be incorporated into future revisions of the ROV. Major hardware components were then introduced that included microcontrollers and dc motors. Again, microcontrollers would be incorporated into the project in future revisions. Multisim circuit simulation software from National Instruments was introduced, but not used in building the kit. Soldering (an essential skill for the project) was also covered.

The basic concepts were presented to the students in a sequence of laboratory exercises during roughly the first three weeks of the Summer Bridge program, and the kit was assembled and tested during the last week. Students also gave a presentation on the project during the final week.

The sequence of lecture presentations and associated lab exercises are shown in Figure 1. Each day, the class met during the afternoon, from 1 pm to 5 pm. Each afternoon consisted of three hours of lab

Week 1		
7/6	1-4pm	Soldering Lab ,
	4-5pm	Electrical Circuit Lecture
7/7	1-4pm	Electrical Circuit Lab
	4-5pm	Electronic Components Lecture

Week 2		
7/11	1-4pm	Electronic Components Lab
	4-5pm	Multisim Lecture
7/12	1-4pm	Regulated Power Supply Lab
	4-5pm	Digital Electronics Lecture
7/13	1-4pm	Digital Electronics Lab
	4-5pm	Microcontrollers Lecture

Week 3		
7/18	1-4pm	Microcontroller Lab
	4-5pm	DC Motor Applications Lecture
7/19	1-4pm	Project
	4-5pm	Engineering Project Management Lecture
7/20-21	1-5pm	Project

Week 4		
7/25	1-5pm	Project
7/26	1-5pm	Final Testing
7/27	1-5pm	Presentation Preparation
7/28	1-5pm	Presentation

Figure 1. Schedule.

exercises followed by an hour of lecture presentation. The lecture provided the background necessary for completion of the laboratory exercises on the following day. The first lab the students attended consisted of learning to solder and de-solder. The students then attended a lecture on electrical circuits which familiarized the students with the basic circuit laws. The associated lab is essential for the freshman engineering students in that it provides an opportunity to apply the new concepts, and perform troubleshooting. The purpose and behavior of various electrical components were then introduced. During the lab, students were familiarized with the use transistors, resistors, capacitors, push buttons, and diodes. Students were then introduced to Multisim circuit simulation software from National Instruments which, though not used in the present project, will be used by the students when they progress to higher academic levels. The power supply lab consisted of reproducing a schematic of a regulated power supply in Multisim, simulating the circuit, and finally building the power supply on a prototyping board. Additional lecture presentations on digital electronics, how to build a simple regulated power supply, dc motors, microcontrollers and the engineering process, were given. Labs on digital electronics and the regulated power supply were also provided, although these features were not incorporated into the present project. The material on digital electronics included the use of AND and NOR gates and how to use and convert binary/hexadecimal numbering systems. During the microcontroller presentation, the students were shown how to identify the parts of a microcontroller and the programming process. DC motor applications were presented along with the H-bridge method of DC motor control, which uses a pulse-width modulation (PWM) input to control a voltage signal to the motor, permitting speed as well as rotation direction of the motor. Some aspects of the engineering process were also discussed (for example, the use of a flowchart in troubleshooting, and the Gantt chart) were introduced, though not applied to this project.

ELECTRICAL AND MECHANICAL DESIGN

The kit (The ROV-In-A-Box Underwater Robot Project Kit, Rev 2.5.2, Copyright © 2006-2008 by Karen Suhm) included all of the parts and a basic instruction manual for building the ROV.

The frame of the ROV (Figure 2) was constructed from 17 5-inch lengths of ½" PVC and 22 PVC joints. The frame consists of two horizontal rectangular 13" x 13" sections separated by four vertical support members connecting the centers of each side, giving an overall height of 7.5".

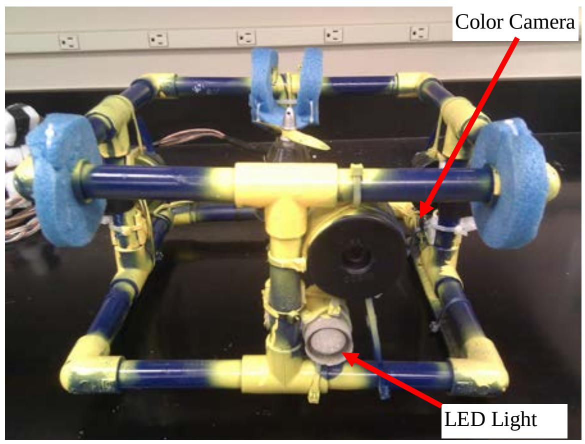

Figure 2. ROV frame.

The mounting brackets for the three thrusters (Figure 3) were then constructed. Each thruster is powered by a 12-volt submersible DC motor. Each thruster housing has two flanges on the base aligned with the axis of the thruster that can be used for mounting.

Figure 3. Horizontal thruster and mounting brackets.

Each horizontal thruster was secured to two mounting brackets. Each mounting bracket was constructed from a PVC tee-joint, cut so that it will snap to the frame. A slot is cut into each mounting bracket for the flanges of a thruster to be inserted. A thruster is secured to each mounting bracket by passing a cable tie through a hole drilled in each flange and two holes drilled in the associated mounting bracket.

The mount for the vertical thruster (Figure 4) consisted of a length of PVC pipe attached to the frame by two PVC tee-joints, one at each end, cut so that they could be snapped to the frame. The flanges of the thruster were inserted into a slot cut into the PVC pipe, and secured in place with cable ties.

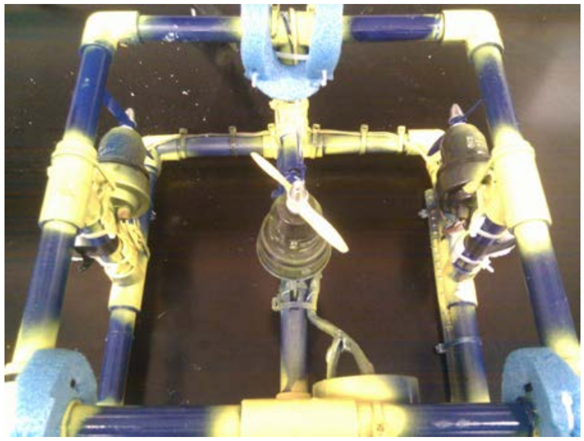

Figure 4. Vertical thruster.

The power supply used for the ROV is an external Werker 12V sealed lead-acid (SLA) battery (Figure 5).

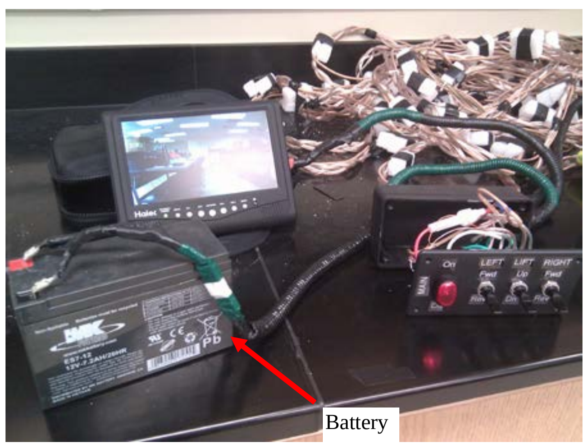

Figure 5. ROV battery.

The control box was then assembled (Figure 6). The control box consists of 4 switches (1 SPST rocker

Figure 6. Control box front panel.

switch and 3 DPDT switches) on the front panel, a plastic housing, an RCA plug, and a battery hook up. The wiring diagram is shown in Figure 7. The color camera and LED light were then secured to the frame using cable ties. The thrusters, camera, and light, were then connected to the control box via a 100-foot

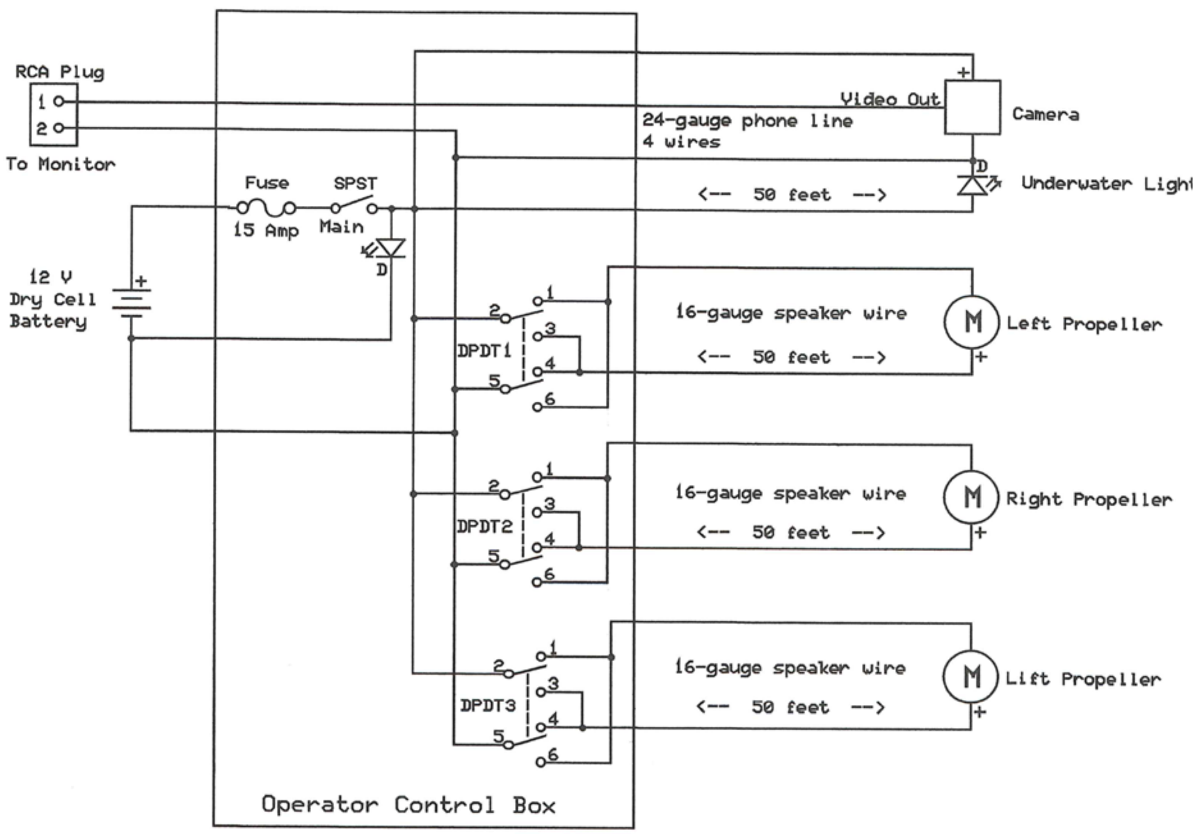

Figure 7. Control box wiring diagram.

tether consisting of three 100-foot speaker wires and a 100-foot telephone cord. Each thruster was connected to a corresponding 3-position switch and the power supply using one of the 100-foot speaker wires. This permits each horizontal thruster to be driven forward or in reverse, or stopped. The horizontal thrusters can then be used in combination to provide forward thrust, reverse thrust, clockwise rotation, and counter-clockwise rotation. The vertical thruster could be used to provide upward thrust, downward thrust, or stopped. The 100-foot 4-wire telephone line was used to attach the camera and light to the RCA plug and power supply. The connections to the components on the ROV were wrapped with electrical tape to insure that they were watertight.

To provide buoyancy, two 1-inch square by 1-foot long blocks of Styrofoam were secured to the ROV (one on the left upper and one on the right upper PVC pipe sections of the ROV frame) using cable ties (Figure 8).

Figure 8. Buoyancy test.

For ballast, two 1-foot lengths of rebar (one on the lower right and one on the lower left PVC pipe sections of the ROV frame) were secured by cable ties. A ½” x ½” Styrofoam block was attached to the tether every 1½ feet to provide buoyancy for the tether. The ROV was placed in a water tank, and the Styrofoam and rebar sections on the ROV frame were trimmed until the ROV was neutrally buoyant and level.

COST ANALYSIS

Funding was provided by the Sure-Step Program. Supplies included miscellaneous items including wire, solder, soldering iron, PVC cement, electrical tape, cable ties, sandpaper, and spray paint.

Item	Vendor	Price
ROV-in-a-box	!nventivity	$349.67
Haier HLT71 7” LCD TV	Amazon.com	$ 75.92
Supplies	Lowe’s Hardware	$ 50.00
Total		$475.59

Table 1. Expense Report

DESIGN CONSIDERATIONS

The power system included a fuse as a safety measure to prevent electric shock. Students were required to wear eye protection and closed-toe shoes during the assembly and testing of the ROV.

The team met with their advisor on a weekly basis during the Fall Semester to receive instruction. The four team members were each assigned to one of three task areas. One member was assigned to researching metal-sensing circuits that could be used for underwater metal detection. After two weeks, the student conveyed the requested information to the advisor, and a preliminary circuit was selected. The student is constructing the circuit on a prototyping board for testing. Based on the results of the test, the circuit will be rejected or modified. A second student was assigned to investigating suitable H-bridge ICs for the thruster control. Two students were assigned to the mechanical design of the revised ROV. They have designed a new frame which will allow the addition of a water-tight canister for holding onboard circuitry. The students also have the design for the canister and have created an exploded-view schematics in SolidWorks.

The team members are thus gaining additional specialized knowledge and experience in new areas, and learning the process of engineering design in developing conceptual solutions to engineering problems. It is hoped that new Freshman members will be identified for the upcoming Summer Bridge program. These individuals would then be assigned suitable tasks for the ROV. It is envisioned that, eventually, student teams at all academic levels will become involved in the ongoing ROV project.

FUTURE WORK

Students will incorporate an onboard microcontroller, allowing implementation of the following features: (1) a user-friendly human interface to the thrusters using a joystick, and (2) display of depth and direction information on a laptop screen. The USB joystick will input steering signals to a laptop, which will encode the information as a serial signal to the onboard microcontroller via an RS-232 serial port. The microcontroller will decode the serial input signal to generate pulse-width modulation (PWM) signals. The PWM signals will then be fed to H-bridge ICs (DC motor controllers), which will produce the controlling voltage levels and polarity at sufficient power levels to set the thruster speed and direction (clockwise or counter-clockwise rotation). Information provide by depth and direction sensors on the ROV will be converted to a serial output signal sent to the RS-232 port on the laptop, where the information will be extracted and displayed on the laptop screen. The output signal from the metal-sensing circuit being developed will be fed through an A/D converter to the microcontroller on the ROV. All of the onboard electronics will be housed in the watertight canister being developed. The modified frame design will permit an additional thruster to be added, providing complete freedom of movement along any direction.

As the ROV project develops, other departments could become involved to supply the expertise needed to accomplish desired tasks. A future goal is to combine a video signal with the serial data signal, eliminating the need for a separate monitor, however, this will require programming skills more likely to be found in the Computer Science department than Engineering. Additionally, the ROV may find an application to biology in exploring the ecology of natural bodies of water, requiring the expertise of biologists in helping to define ROV performance requirements.

CONCLUSION

Students participating in the 2011 Sure Step Robotics Research program were asked to complete a survey (Figure 9) on their learning experience. Three of the four students involved in the project responded. The responses are summarized in Table 2. Students reported a positive experience. One student commented, “I thoroughly enjoyed this program.” Another stated, “I enjoyed the project. It really helped strengthen my commitment to being a STEM major.” The third student commented that he would have preferred

What do you think about Sure Step Robotics Research at UCO?

Please take a few moments to tell us your thoughts on Sure Step Robotics Research at UCO. Your comments will help us improve future activities. Thanks!

Event Date: Summer 2011

	QUALITY RATING					
	Strongly Agree 5	Agree 4	Neutral 3	Disagree 2	Strongly Disagree 1	Don't Know 0
1. The training lecturers were useful.						
2. The laboratory exercises and training were useful.						
3. I developed a good understanding of problem solving in Engineering.						
4. I learned how to work in teams.						
5. I had a strong background in science and math prior to engaging in this program.						
6. This program met my expectations.						
7. This program has increased my commitment to become a STEM major.						
8. This program helped me to learn about robotics research.						
9. I will continue with robotics research after joining Sure Step Robotics research.						

Do you have any suggestions for improvement, or other comments about Sure Step Robotics Research at UCO?

Figure 9. Survey Form.

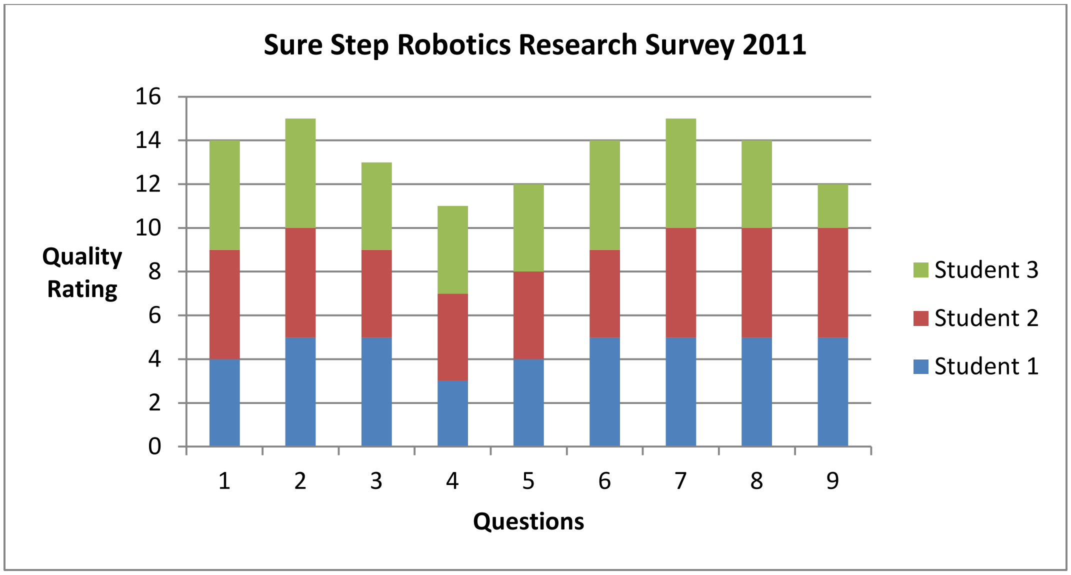

Table 2. Survey results.

longer lab times in order to allow more time to design the ROV. All of the students agreed that the training, lecture, and laboratory exercises, (Questions 1 and 2) were useful. Also, all students agreed they developed a good understanding of problem solving for engineering (Question 3), a component in their transformation to becoming a future engineer. However one student dropped out of the program before the end of the summer, and another reported on the survey that he would not be continuing with the research. This suggests that there are some problems related to motivation and enthusiasm that need to be addressed. Some possible measures might be: (1) provide students with a clearer vision of the mission (a timeline for delivery of project components), (2) more frequent group meetings, (3) providing a dedicated space in which to perform the work, and (4) timely feedback on participation of individuals in the group. From the survey data, two people had positive responses with respect to teamwork (Question 4) and continuing with the project (Question 9), while the third was neutral on Question 4, and negative on Question 9.

In conclusion, the program was successful from the standpoint of providing the necessary training to complete the project, and in providing the students with a better understanding of the engineering process, but changes to the group interaction are required to maintain the participation of students in the future.

REFERENCES

[1] Wise, K.C. (1996). Strategies for Teaching Science: What Works?The Clearing House, July/August, 337-338.

Study of middle and high school science found 140 published comparisons between traditional teaching and alternative instruction (inquiry- oriented approached). Inquiry instructional strategies averaged thirteen percentile points higher in achievement measure over traditional text-lecture modes of instruction.

[2] Heise, D., Asserting the Inherent Benefits of Hands-On Laboratory Projects vs. Computer Simulations, Consortium for Computing Sciences in Colleges, Central Plains Conference, (2006).

[3] Felder, R. M., Felder, G. N. and Deitz, E. J., A longitudinal study of engineering student performance and retention. V. Comparisons with traditionally-taught students. J. ENGNG Edu., 1998, 87, 469-480.

[4] Bransford, J. D., et al., How People Learn: Brain, Mind, Experience, and School, Washington, DC: National Academy Press, 2000.

[5] Mataric, M. J., Robotics Education for All Ages, Proceedings, American Association for Artificial Intelligence Spring Symposium on Accessible, Hands-on AI and Robotics Education, Palo Alto, CA, Mar 22-24, 2004.

[6] Robotics as a tool for immersive, hands-on freshmen engineering instruction, http://cres.usc.edu/pubdb_html/files_upload/567.pdf

[7] Mezirow, J., Transformative Learning: Theory to Practice, New Directions for Adult and Continuing Education, No. 74, Summer 1997, Jossey-Bass Publishers.

[8] Suhm, Karen, The ROV-In-A-Box Underwater Robot, Rev. 2.5.2 (2008).

[9] Moore, S.W., et al. Underwater Robotics: Science, Design and Fabrication: Marine Advanced Technology Education Center. Monterey, CA. (2010).

[10] Cutcher, Dave, Electronic Circuits for the Evil Genius, 2/E. McGraw-Hill/TAB Electronics. (2010).

[11] Carryer, Edward, et al., Introduction to Mechatronic Design. Prentice Hall (2010).