Flipping the Classroom for Enhancing Learning and Designing in an Embedded Systems Class

Nansong Wu, Kaiman Zeng, Jacob Weidenfeller, and Xiaokun Yang
nwu@atu.edu, kzeng@atu.edu, jweidenfeller@atu.edu, yangxia@uhcl.edu

Abstract **- Embedded system design has become an attractive field for engineering students. The high demand of embedded system engineer in the job markets further promotes enrollments in embedded system courses. Thus, there is a need for the courses to link theoretical knowledge to real-life applications. Hands-on projects can facilitate students' curiosities to explore the practical problems and challenges from the real-world for a deeper understanding of the cutting-edge knowledge in electrical and computer engineering. Incorporating flipped classroom in engineering courses can engage students. Researchers have noticed greater engagement of students during the flipped portion of the course as well as increased opportunity to communicate with students individually. Thus, to encourage active student participation in the class, develop critical thinking and reasoning, we propose a flipped classroom method to provide solutions to facilitating critical thinking and active learning in class. Rather than reading and complete activities outside of class and then coming to class to hear a content-intensive lecture, students in flipped classes can use short video lectures and other content-rich preparatory work and then, during the onsite class session, participate in discussions, exercises, and projects. An assessment plan is developed to evaluate the redesign. Preliminary data is collected through course feedback and evaluation. Preliminary implementation shows that the redesign of the course has great potential for success.**

Index Terms – Flipped-classroom, Embedded systems, Robotics.

INTRODUCTION AND LITERATURE REVIEW

At Arkansas Tech University, the Microprocessor System Design course is offered to the electrical and computer engineering students immediately after their first-year study. Traditionally, the Microprocessor System Design course is taught in the way of two class meets of 80 minutes each per week. The laboratory and experiments are part of the class meeting. I.E. The instructor normally gives a short lecture, and then continue the experiment in the lab. Base on the experience learned in previous semesters, we found the class meet time is not sufficient for students to complete longer lab assignment and comprehensive projects after the delivery of the lectures. It was not uncommon for students to complete their labs and project outside the class time. Causing disconnections between the experiments and the lectures. It is more difficult for students to get together and perform engineering teamwork on their projects. It was also discovered that many students need help with some course contents outside the classroom. But they have limited resources besides the office hours that they can use to seek help.

Embedded processors can be divided into two categories: ordinary microprocessors and microcontrollers. Embedded system design has become an attractive field for engineering students. Working with embedded systems can be highly motivational for the students. In addition, the high demand of embedded system engineer in the job markets further promotes enrollments in embedded system courses. Thus, there is a need for the courses to link theoretical knowledge to real-life applications.

This educational objective of embedded system courses can be met through the implementation of hands-on learning, which can include lab experiments and projects. Researchers suggest that effective courses provide hands-on learning experiences, such as robotic programming project [1]. These projects can facilitate students' curiosities to explore the practical problems and challenges from the real-world for a deeper understanding on the cutting-edge knowledge in electrical and computer engineering [2]. Moreover, diversified microcontroller projects can motivate students to learn, and promote critical thinking [3].

Incorporating flipped classroom in engineering courses can engage students. Researchers have noticed greater engagement of students during the flipped portion of the course as well as increased opportunity to communicate with students individually [4]. Furthermore, Smith [5] implemented a first year embedded systems design course which includes a quarter long project with flipped classroom setting. The results demonstrated that the course helped the students feel excited about their major, and understand how their major can make a difference in the world. Moreover, Redekopp, and Ragusa evaluated flipped classroom strategies and tools for computer engineering and suggested focusing more on the specific active-learning techniques that can be used in place of traditional lectures, rather than on how best create the offline lecture content [6].

Thus, to encourage active student participation in the class, develop critical thinking and reasoning, we propose a flipped classroom method to provide solutions to facilitating critical thinking and active learning in class. Rather than reading and complete activities outside of class and then coming to class to hear a content-intensive lecture, students in flipped classes can use short video lectures and other content-rich preparatory work and then, during the onsite class session, participate in discussions, exercises, and projects.

DEVELOPMENT OF COURSE CONTENTS

In this course redesign project. The instructor pre-recorded selected lectures and post them for the students to view as pre-class assignments. The recorded contents are continuously available to the students for review until the end of the course. The class contact time is used primarily on the interactivities between the instructor and the students, such as completing guided worksheets to assess the course contents. Active Learning is employed to let the students work collaboratively on solving programming problems that support the weekly lab assignment, and building circuits to interface external devices with the microcontroller. After watching a demo of the final objective, students started to break down the project into milestones: robot, microcontroller, programming, 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. The in-class activities will be carefully designed to measure student understanding of course topics. During the course, students will submit reports on two projects, and give a demonstration and presentation on their final project.

For example, Figure 1 shows the video explanation of pulse-width modulation (PWM). This video is one of the videos that explains the important concepts involved in this course. With the concepts and explanations available on video, the students can rewind the video and study what they didn't understand initially.

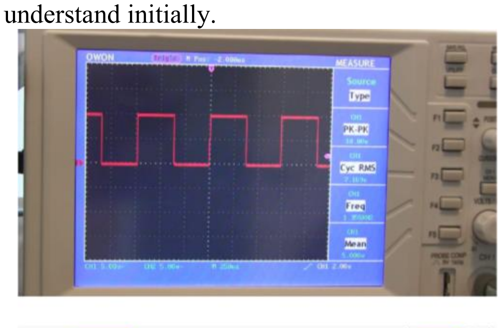

FIGURE 1
VIDEO EXPLANATION OF PULSE-WIDTH MODULATION (PWM)

Figure 2 shows a video demonstration of the binary counter project using Texas Instruments MSP430 microcontroller and LED display. This is one of the projects to support an important concept – interrupts.

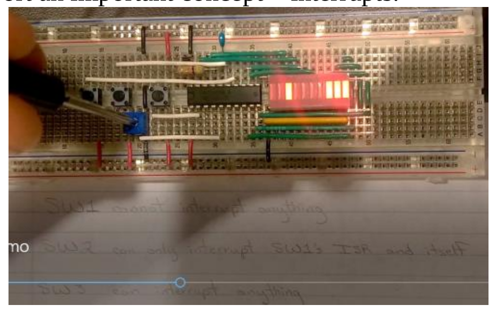

FIGURE 2
VIDEO DEMONSTRATION OF THE BINARY COUNTER PROJECT USING TEXAS INSTRUMENTS MSP430 MICROCONTROLLER AND LED DISPLAY.

I. Hardware Platform

A mini robot chassis is selected to ensure the small footprint of the completed robot. So that the track build for the robot can fit in the limited lab space. The microcontroller board was changed from RoMeo version 2 revision 3 microcontroller board proposed in the proposal to Romeo BLE mini to fit in the much smaller footprint of the robot platform and to provide integrated Bluetooth connectivity. Using smartphones, the students are able to remotely control their robot. For example, they can use a smartphone to remotely start their robot, to steer the robot and reset the position on the track. The total cost for each robot kit together with the microcontroller board is successfully controlled to be within 50 USD.

II. Robot Competition

Figure 3 shows a prototype of the autonomous robot. The robot has a width of 109mm. A track in the size of 4 by 2 meters has been built and later remodeled based on test runs of prototype robots. A course robot competition will be held.

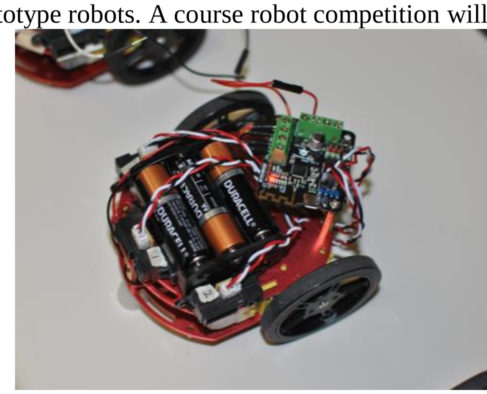

FIGURE 3
A PROTOTYPE OF THE AUTONOMOUS ROBOT.

Table 1 is an example of the scoring table for the autonomous robot competition. Student groups first compete on the speed of their robots by run the robots for up to 5 laps.

The average lap time is used to rank the robots. During this test, 2 points are taken for each occurrence of the robot running into walls or resetting. The robots then take on an endurance race. A chasing race is added based on students' good feedback and previous experience. Two closely ranked robots will chase each other on a closed loop track. A complete tournament is not carried out due to the limitation of class time. Therefore no point is allocated for the chasing race. Finally, all robots will be lined up, and a committee will rate on the build and aesthetics. The average score of the groups is expected to be around 80. This competition weights 15% of the final grade.

TABLE I
AUTONOMOUS NAVIGATION ROBOT COMPETITION SCORING TABLE

	No Score	50% of Possible Points	75% of Possible Points	Full Score
Average lap time (allow up to 5 laps) 40 Points	Does not complete one lap	Greater than 115% of the average lap time	100% to 115% of the average lap time	Less than the average lap time
Number of laps before accidental stop (allow up to 10 laps) 40 Points	Does not complete one lap	Completes 50% of the average number of laps	Completes 75% of the average number of laps	Above the average number of laps
Build and aesthetics (cable management, other functions, creativity, and originality) 20 Points		Include at least two scoring criterions	Include at least three scoring criterions	Best modification

The project can be a very good start for students who later work on autonomous robot senior design project. For example, an eye-controlled wheelchair [7]. Coupled with 3D objects detection algorithms [8, 9], the project can be extended to a more challenging vision-based autonomous driving robot project in the future course.

DEVELOPMENT OF COURSE ASSESSMENT

I. Anticipated Outcomes

With the concepts and explanations now available on video, the students can rewind the video and study what they didn't understand initially. Students will be more prepared for the class and experiment since they have the chance to research the pre-class questions. The students will have adequate time and more actively engage in the discussion and question-and-answer during the class. They will be exposed in an environment that encourage critical thinking. And they will more likely to perform critical thinking in the class. A series of real-world applications, such as anti-lock braking system, and quad-copters are researched on in the class. Students end up not only having a better understanding of engineering concepts but also greatly improved their research ability.

II. Assessment and Preliminary Implementation

The students will be given an anonymous questionnaire aimed at improving their learning process. The questions will cover the effect of the teaching and learning process, such as the effect on the student's understanding of the course contents, the effect on student's completion of assignments, the effect on interactive learning experience, the effect on critical thinking and reasoning.

We will also perform quizzes in pairs, namely quiz A and quiz B. Quiz A corresponds to the contents of a chapter that are covered using flipped classroom. Quiz B corresponds to the contents of the same chapter that are not covered using flipped classroom. The problems of the quizzes in one pair are carefully designed to provide a consistent level of difficulty. Multiple pairs of quizzes will be offered to generate comparisons over the entire range of teaching and learning of the course. The results will be normalized, compared and discussed to provide conclusions and future improvements of the course and the method.

Class feedback gained from preliminary implementation shows that the redesign of the course has great potential for success. The course evaluation received a much higher participation rate of nearly 80%. The criterions related to the course structure and instruction methods are rated much higher than both the department average and college average. There are also improvements in these criterions in the value of 0.11 to 0.44 (5 point scale) over the evaluation results from the last semester.

On the course implementation, the students commented "The overall idea of the way this course is planned out is a good idea. I believe that providing a project-based course is great for learning." And "Hands on training! Lots of hands on stuff which is the way I and most engineering students, in my opinion, learn the best. Absolutely loved this class and looked forward to it every day. Since we had our own projects it really engaged the student outside of the classroom."

On the final project, one team of three students commented "This project was very fun and considered a huge success by my entire group. We used a small two-wheel drive robot using the BLE Mini microcontroller. We managed to create codes to maneuver our robot in a very precise and efficient manner. The project was a very positive experience and was definitely a lot of fun."

ACKNOWLEDGMENT

This project was supported by course redesign research and scholarship from Arkansas Tech University. We thank our colleagues from the department of electrical engineering and mechanical engineering, director of undergraduate research Dr. Hemmati, and Ms. Eubanks from the academic affairs who provided insight and expertise that greatly assisted the project.

REFERENCES

[1] Schleter, W., and Biegalski, A., "Implementing a Robotic Programming Project in a First Semester 'Programming for Engineers' Course", *Proceeding of the 7th Annual First Year Engineering Experience Conference*, Roanoke, VA, August, 2015.

[2] Wu, N., and Zeng, K., "Embedded System Based First-Year Engineering Course with the Aid of Online Simulation and Social Media", *Proceeding of the 8th Annual First Year Engineering Experience Conference*, Columbus, OH, August 2016.

[3] Fang, V., SanGregory, S., and Kohl, C., "Diversified Projects in Microcontroller Class Enhances Undergraduate Students' Learning, Design and Research", *The 122nd ASEE Annual Conference and Exposition*, Seattle, WA, June, 2015.

[4] Vidic, N., Clark, R., and Claypool, E., "Flipped Classroom approach: Probability and Statistics Course for Engineers", *The 122nd ASEE Annual Conference and Exposition*, Seattle, WA, June, 2015.

[5] Smith, H., "An Embedded System Design Experience for First Year Computing Majors", *Proceeding of the 8th Annual First Year Engineering Experience Conference*, Columbus, OH, August 2016.

[6] Redekopp, M., and Ragusa, G., "Evaluating Flipped Classroom Strategies and Tools for Computer Engineering", *The 120nd ASEE Annual Conference and Exposition*, Atlanta, GA, June, 2013.

[7] Thota, J., Vangali, P., and Yang, X., "Prototyping An Autonomous Eye-Controlled System (AECS) using Raspberry-Pi on Wheelchairs", *International Journal of Computer Applications*, Vol. 158, No. 8, January 2017, pp. 1-7.

[8] Zeng, K., Wu, N., and Yen, K., "A Color Boosted Local Feature Extraction Method for Mobile Product Search", *International Journal on Recent Trends in Engineering and Technology*, Vol.10, No.2, January 2014, pp.78-84.

[9] Zeng, K., Wu, N., and Yen, K., "Local Visual Feature Detection and Description for Non-rigid 3D Objects", *International Journal of Signal Processing*, Vol.1, 2016, pp.114-119.

AUTHOR INFORMATION

Nansong Wu Assistant Professor, Arkansas Tech University, nwu@atu.edu
Kaiman Zeng Visiting Assistant Professor, Arkansas Tech University, kzeng@atu.edu
Jacob Weidenfeller Graduate Assistant, Arkansas Tech University, jweidenfeller@atu.edu
Xiaokun Yang Assistant Professor, University of Houston-Clear Lake, yangxia@uhcl.edu