New Orleans JAZZED about Engineering Education

Paper ID #16948

Innovative Course Modules for Introducing ECE to Engineering Freshmen

Dr. Girma Tewolde, Kettering University

Girma S. Tewolde received the B.Sc. degree in Electrical Engineering from Addis Ababa University, Addis Ababa, Ethiopia, the M.Eng.Sc. degree from the University of New South Wales, Sydney, Australia, and the Ph.D. Degree in Systems Engineering from Oakland University, Rochester, Michigan. Dr. Tewolde is currently an Associate Professor of Computer Engineering in the Electrical and Computer Engineering Department of Kettering University, Flint, MI. His areas of interest are in Embedded Systems, Sensor networks, Mobile Robotics, Evolutionary Optimization and Swarm Intelligence for optimization and engineering applications. Dr. Tewolde is a Member of the IEEE Computer Society and the IEEE Robotics and Automation Society.

Innovative Course Modules for Introducing ECE to Engineering Freshmen

Girma S. Tewolde
Department of Electrical and Computer Engineering
Kettering University, Flint, MI 48504

Abstract:

The curriculum for all Engineering majors in our institute includes an inter-disciplinary course that exposes all freshman students to the different areas of engineering, including Mechanical, Industrial, Manufacturing, Electrical and Computer Engineering. The course is co-taught by multiple instructors, from all the different disciplines. It is made up of short lecture sections and longer laboratory activities. The main goal is to introduce the students to the basic principles, applications, and practical tools commonly used in the different fields. This paper presents an innovative course development for the ECE component of this inter-disciplinary course. The course offers effective, hands-on and practical activities to enhance the students' learning experiences. Another important feature of this course is that the students are presented with challenges to exercise their creative thinking skills and come up with innovative applications to the basic concepts covered in the class. The main focus topics of the ECE component of the course include electrical/electronic components & circuits, PCBs, microcontrollers and programming, sensors and actuators, and robotics. Low-cost, open-source, and easily accessible hardware and software tools are developed for the course. A pilot offering is currently underway, and a survey tool is developed to gauge the effectiveness of the curriculum. Even though results of the assessment are not yet available for this conference, the paper presents and discusses this survey tool at the end. The authors are grateful to the support of the Kern Family Foundation for the course development through the institute's KEEN Internal Topical Grant program.

I. Introduction

Introduction to Electrical and Computer Engineering courses are common in many institutes across the country for freshman or sophomore students[1,2]. The goal of such courses is to provide general introduction to the field of ECE and talk about the main areas of applications, problem solving, professional career opportunities, technology, ethics, and other related topics.

Instead of providing just theoretical presentation about the field, this proposed course offers a more practical approach for effective ways of achieving the same objective, with the additional benefit of enhancing student engagement and their learning experience in the process. To this end, the main strength of this work is its focus on a number of hands-on practical activities that are created for the students to perform.

For the success of such introductory courses, it is essential to identify important topics that need to be covered and develop laboratory kits that offer opportunities for creativity and exploration in a meaningful manner, at manageable complexities and affordable costs. Small mobile robots have been a common choice for many universities for teaching their freshmen introduction to ECE courses[3-6]. Robots have been proven to be effective and engaging tool to excite the curiosity

of students. Over the years several schools, including our university, have used the LEGO MINDSTORMS NXT[7] or similar kits for building robots, and learning about sensors and programming. Now with the proliferation of open-source hardware and software systems and online user communities it is increasingly becoming easier to offer courses using lower-cost products, with more accessible kits for building simple to complex systems.

The robotics parts of the newly developed course modules presented in this paper utilize a low-cost simple mobile robotic base[8]. It has two wheels with their own drive motors that can be controlled both for speed and direction. The popular Arduino[9] microcontroller is introduced as a control unit for driving the robot. Students learn about the design of circuits that are required to drive the motors from the low-level digital signals generated by the microcontroller. For this purpose they are provided with an in-house developed motor shield that attaches to the Arduino microcontroller for driving the motors. Students learn about various robotic sensors, and develop basic autonomous vehicle behaviors using light and ultrasonic sensors. The communication aspect is dealt with by introducing Bluetooth for remotely controlling the robot from a PC or Smartphone.

II. Course Structure

This introduction to ECE course in our university is offered as part of a general introduction to multiple engineering disciplines, including industrial, mechanical, electrical and computer engineering. Currently, first year students from all engineering majors or those with undecided majors are required to take it in their first or second freshman semester. The total number of students being served with this course is approximately 400 per year. This paper talks about the ECE component of the course and presents the newly developed modules and laboratory activities. Through this course the students get exposed to the fundamental concepts of the field of ECE, learn about the basic electrical & electronic components, gain knowledge on how to wire circuits, use basic instruments such as multi-meter and oscilloscope; and develop skills in PCB circuit assembly, testing and troubleshooting. The students also learn about microcontrollers and how to use them to build embedded systems through easy to learn mobile-robots, sensors, and programming. Robots are in general found to be fun and engaging ways to attract the students' attention and to inspire them to tackle even harder challenges.

The curriculum also aims to instill the Entrepreneurial mindset[10]. The big picture of the main concepts covered in each topic is explored further by looking at related real-world applications and current technological innovations, through class discussions and research homework assignments. This helps raise the curiosity level of the students. They are asked to make connections between the different topics and relevant real-world applications, and present potential opportunities with customer value creation in mind.

The students spend five weeks of a semester to work on the ECE topics. Each class meeting is two hours long per week. The students are placed in teams of a maximum of three students selected from different engineering disciplines. To make effective use of the class time, the course material that includes background information, tutorials, and laboratory activities, is made available online for the students. The class is run in a "flipped" style. The students are also provided with copy of the software tools used in the course and they borrow the laboratory kits

for the duration of the course. The students are expected to come prepared for each class period. The instructor spends twenty to thirty minutes of the class period reviewing the most important points for that class and answering student questions, before letting the class start working on the practical activities.

In each class session, there are a few pre-designed practical tasks the students complete that are focused on the main topics for that class. These activities help students demonstrate how well they understand the concepts by completing practical laboratory experiments, either in simulation or on a real physical setup. Each class period ends by giving students open-ended problems that expect them to apply the knowledge they gained from that day or other previous lessons, and making connections to practical real-world applications. These often motivate them to think outside the box and to come up with creative solutions to existing problems or develop new applications or use-cases based on the tools they are learning.

III. Course Modules

This section presents the course modules developed for the Introduction to ECE class.

Module 1: In the first course module students get introduced to electrical and electronic circuits. The NI Multisim[11] & Ultiboard[12] software for circuit design, simulation and board layout are used as the software tools. A practical example on the design and simulation of a traffic light circuit is used to illustrate the concepts and provide meaningful experience for the students. Circuit components such as resistors and capacitors, and electronic components such as oscillators and timers, and digital logic gates are introduced and used to build a hardware realization of traffic light circuit. A potentiometer is used to control the timing of the signals in the circuit.

Topics covered:

- Introduction to Electrical & Electronic Circuits
- Circuit Design and Simulation tools
- Printed Circuit Board (PCB) Design
- Entrepreneurial-mindset (e-mindset) challenge

Tutorials:

- Introduction to Circuits
- Introduction to Entrepreneurial Mindset

For the e-mindset challenge the students are asked to work on the following question to inspire their curiosity:

- Think about other practical and useful applications of a timer or clock. Explore all possible application domains, such as in personal, household, industrial, automotive, etc.

The students are expected to work in teams, brainstorm their ideas with their team, and present a report on their innovative solutions.

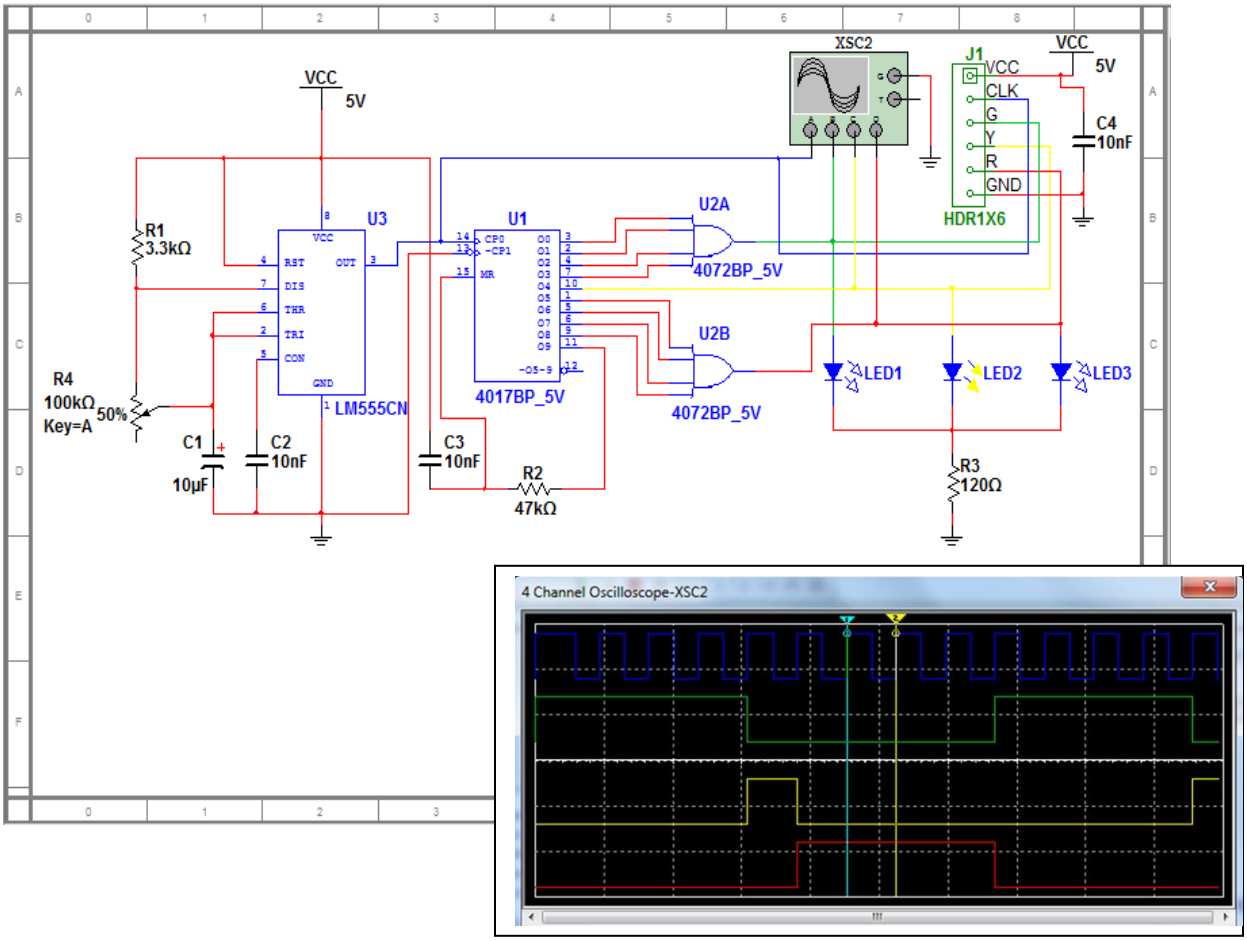

Figure 1: Course Module 1 – traffic light circuit design, simulation and PCB layout

Module 2: In the second course module students get introduced to Printed Circuit Board (PCB) assembly process and learn how to utilize circuit testing tools, such as voltmeter, ohmmeter and oscilloscopes. The students get to assemble the traffic light circuit board they designed in Course Module 1. They learn how to identify the basic electrical/electronic components, determine or measure their values and develop the necessary skills to solder the circuit components on a PCB. Finally, they apply testing and troubleshooting techniques to verify the correct operation of their circuit, by using an oscilloscope to display the signals from test points on the PCB.

Topics covered:

- Reading and understanding schematic diagram circuits
- Identifying common electrical/electronic components, determining their values, and use of basic measuring instruments
- Assembly and soldering of printed circuit board (PCB)
- Functional test of the assembled PCB using standard laboratory equipment/instrumentation
- Troubleshooting techniques to identify and fix problems in circuits
- Entrepreneurial-mindset challenge

Tutorial:

- Introduction to Electronic circuit assembly and soldering techniques

For the e-mindset challenge the students are asked to work on the following question to inspire their curiosity:

- Propose ideas for enhancing the functionality or adding new useful features to the basic traffic light circuit developed in modules 1 and 2. Additional inputs may be considered for providing controls to the traffic light circuit in different ways.

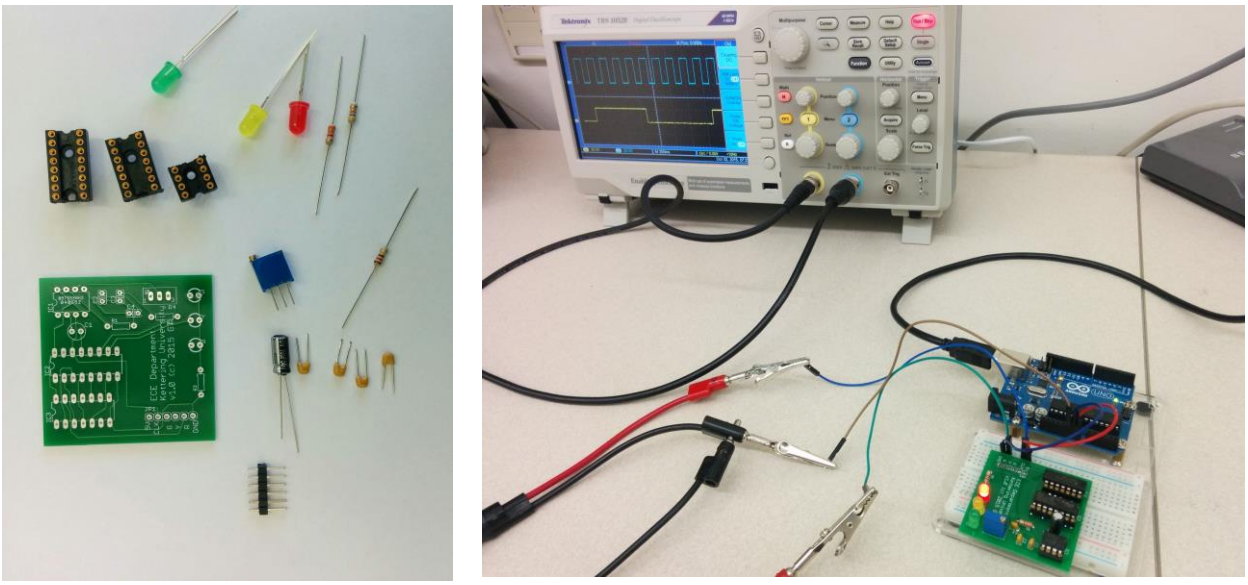

Figure 2: Course Module 2 – PCB assembly and testing

Module 3: The topics explored in the third course module are Microcontrollers and Programming. For the practical activities of this module the Arduino[6] microcontroller is chosen because of its popularity, ease of use for beginners, low-cost, and the availability of open source hardware designs, software libraries, and free development software tools. The large online user community also is believed to inspire the students to open up their minds to explore endless application ideas. The traffic light circuit that was implemented in the previous two course modules is re-created again, but this time using an Arduino microcontroller, thus demonstrating to the students the different options available for application development. This helps them appreciate the real engineering approaches engineers follow in evaluating alternative design options based on criteria such as cost, flexibility, development time, etc.

Topics covered:

- Introduction to microcontrollers and embedded systems
- What is Arduino?
- The Arduino programming process
- Basic digital input and output operations, using switches, resistors and LEDs
- Circuit prototyping on a breadboard
- Recreate the traffic light circuit with additional features using Arduino, basic circuit elements, and programming
- Entrepreneurial-mindset challenge

Tutorial:

- Arduino tutorial – part 1

```
// Traffic light program with override
// and timing control inputs
#define  greenPin        10
#define  yellowPin       11
#define  redPin          12
#define  switchPin       2
#define  potPin          A0

//initialization code
void setup() {
  pinMode(greenPin, OUTPUT);
  pinMode(yellowPin, OUTPUT);
  pinMode(redPin, OUTPUT);
  pinMode(switchPin, INPUT);
}

//Complete the code for the program logic
void loop() {
   //…
}
```

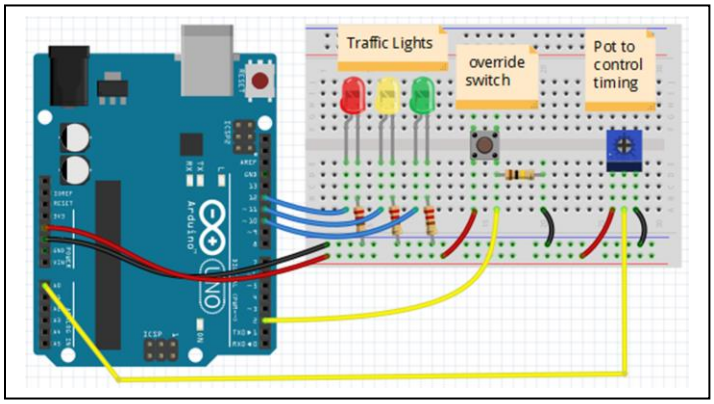

Figure 3: Course Module 3 – Re-creating a flexible traffic light circuit using Arduino

For the e-mindset challenge the students are asked to work on the following questions to help them make connections between different approaches for solving problems:

- You are now able to see different ways of implementing a traffic light circuit using: a) a hardware approach, b) a microcontroller, programming, and basic circuit elements. Discuss the benefits and drawbacks of each approach based on different criteria such as: cost, complexity, time-to-market, and design flexibility.
- Research and brainstorm/painstorm with your lab partners and present innovative ways of improving a specific existing product or service by using a microcontroller such as the Arduino. For extra credit opportunity propose a new product or service with good analysis on its market potential.

Module 4: In the fourth module students are introduced to basic concepts of mobile robotics, including actuators, sensors, and controls that are integrated to allow robots operate in an autonomous manner. Also, Arduino programming features for dealing with analog input and output using ADC and PWM, control structures, and debugging using serial monitor are introduced. Ultrasonic sensor is used for distance measurement, obstacle detection, and collision avoidance. Photoresistor based light sensors are used to implement line following algorithm. As a final assignment for this module students will be required to combine both the light sensors and ultrasonic sensors for implementing a line following algorithm while avoiding obstacles.

Topics covered:

- Introduction to mobile robotics
- Interfacing to motors using motor drive circuit
- Analog input using ADC
- Analog output using PWM for speed control

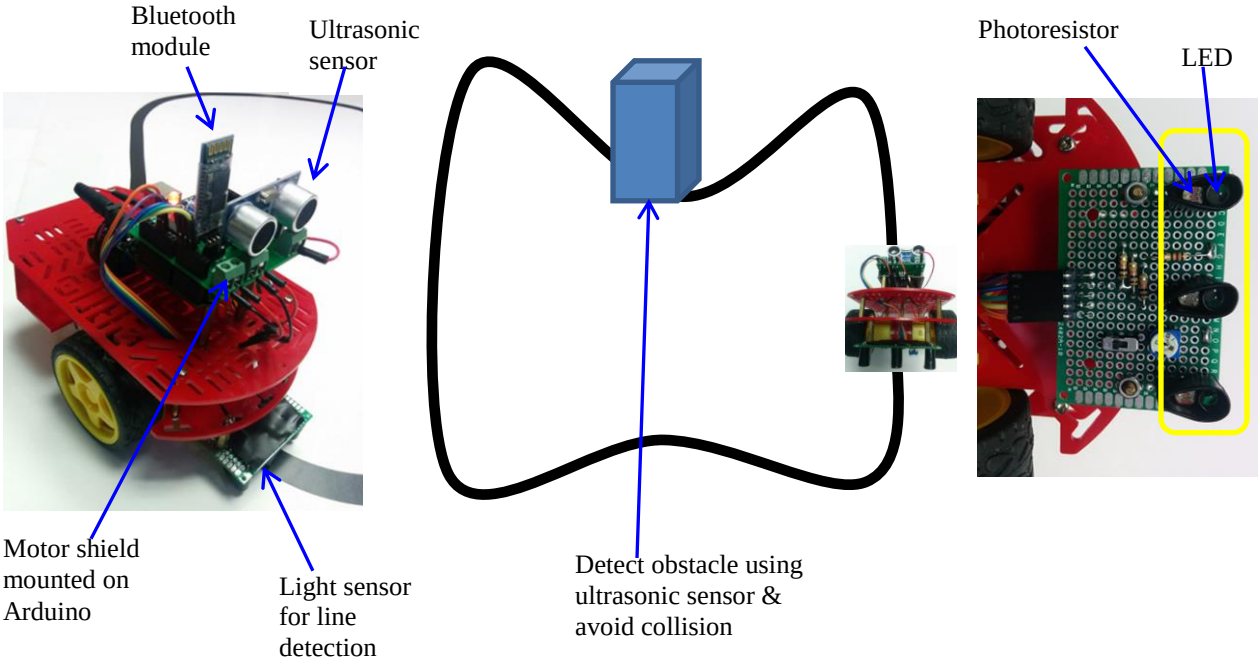

Figure 4: Course Module 4 – Mobile robotics with sensors for intelligent operations

- Basic mobile robot navigation
- Introduction to robotics sensors: ultrasonic and light sensors
- Obstacle avoidance using ultrasonic sensor
- Line following using light sensor
- Combining multiple sensors for improved functionality
- Entrepreneurial-mindset challenge

Tutorial:
- Arduino tutorial – part 2

For the e-mindset challenge the students are asked to work on the following questions so they can try to make connections between the theoretical concepts and real-world applications, and also to inspire their curiosity:

- From the things you interact with every day (at home, in your car, at school, workplace, shopping, restaurant, bank, stadium, the road, etc.) pick one thing and identify the electrical and electronic components, sensors, actuators, microcontrollers, robots, and application programs.
- Research and brainstorm/painstorm with your lab partners and present a specific application (existing or new) for a robotic like system. Think outside the box to consider all kinds of robotic systems (such as mobile, stationary, walking, flying, driving, humanoid, etc.). If you choose existing system or application, discuss innovative ways of improving it.

Module 5: The last module serves as a final project. It first introduces the students to the basic concepts of communication, with a specific emphasis on Bluetooth wireless communication. With advancements in technology students are already familiar with mobile technologies and the available communication options such as 4G-LTE, WiFi, and Bluetooth. After a quick introduction to these techniques the students work on Bluetooth for setting up a communication between their computer or mobile device (phone or tablet) and the mobile robot. The students are provided with an App that they use to send basic remote control commands to the robot. On the robot side they implement their own Arduino program to decode the received commands and provide logic to appropriately respond to the commands. The App also offers an option to instruct the robot to operate in one of two autonomous modes that the students create. The first autonomous mode lets the robot navigate on its own by wandering around in an open space while avoiding obstacles. The second autonomous mode lets the robot navigate by following a line made of black electrical tape, while looking out for obstacles using its ultrasonic sensors.

IV. Assessment Tool

The course modules presented in this paper are being offered for the first time this semester. We have developed a survey as an assessment tool on its effectiveness in student learning. We are running the survey at the beginning of the course and at the end again, and will analyze the data to see the course's impact.

The survey questions try to assess both the technical topic areas of ECE as well as the students' attitude in the entrepreneurial mindset. Below is the list of the questions covered by the survey.

Some of the questions in this survey are borrowed from the article published in the Journal of Engineering Entrepreneurship by Carpenter et al.[13]

How much do you agree or disagree with each of the following sentences?	Select one of the following answers				
	Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1. I am able to recognize basic electrical circuit components (resistor, capacitor, potentiometer, LED, integrated circuit chip, switch, etc.)	1	2	3	4	5
2. I am able to operate tools (such as oscilloscope and multi-meter) for testing the operation of electrical/electronic components and circuits.	1	2	3	4	5
3. I am able to use a computer-aided software tool to design and simulate an electrical/electronic circuit.	1	2	3	4	5
4. I am able to solder and test an electrical/electronic circuit board.	1	2	3	4	5
5. I understand what microcontrollers or embedded processors are and the applications they can be used for.	1	2	3	4	5
6. I am able to write Arduino programs to implement creative solutions for my problem.	1	2	3	4	5
7. I am able to identify basic sensors, such as ultrasonic and light sensors, and their real-world applications.	1	2	3	4	5
8. I am able to explain the use of clocks for electrical/electronic applications.	1	2	3	4	5
9. When confronting a new problem, I am good at devising many possible solutions.	1	2	3	4	5
10. When solving a problem, I tend to try just one solution.	1	2	3	4	5
11. I get discouraged when my solution fails.	1	2	3	4	5
12. I am able to independently gain new information for my problem from various sources.	1	2	3	4	5
13. I understand the concept of appropriate “value proposition”, based on customer needs.	1	2	3	4	5
14. I can list attributes associated with the entrepreneurial mindset.	1	2	3	4	5
15. I collaborate well with others to develop appropriate solutions to problems.	1	2	3	4	5
16. It is clear to me that teamwork skills are crucial to my education and future profession.	1	2	3	4	5
17. When dealing with challenges I like to analyze the situation and make connections to related ideas that could help me solve the problem.					
18. I have a good understanding of the application areas for the fields of ECE and the career opportunities for its graduates.	1	2	3	4	5

V. Discussion and Conclusion

The main objective of this innovative introduction to ECE course presented in this paper is to expose freshmen to the fields of ECE, through exploration of the technological advancements, applications, and the career opportunities. The course is not intended to go in-depth in any of the specific topics introduced in the modules, however, it was primarily meant to offer the students an opportunity to see a big picture and raise their expectations so they know what is to come as

they continue their study in this field. It has been our aim from the outset to keep the curriculum practical so the students stay engaged and inspired to actually build things, learn about the basic debugging tools and skills, and realize that there are many alternate solutions to a single problem. Making connections between various concepts covered in the course modules to real-world applications is also important feature that attempts to stimulate curiosity and challenge them to think outside the box.

At the completion of the course development process, a presentation was made to the campus faculty at which a positive response and a constructive feedback in the area of student assessment received. Based on this feedback we were able to research and refine the assessment tools as presented in the previous section. Faculty training, for the ECE instructors of the course, was also conducted before the course's first offering. The course material is made available online for both faculty and students, so they can work on it at their own pace.

In conclusion, we believe that the newly developed innovative introduction to ECE course modules meet all the initial objectives as presented in the paper. This is still a work in progress, and we will continue to make necessary improvements as we receive feedback from faculty and the results from a comprehensive survey of our students.

VI. Bibliography

1. J. W. Pritchard and Mani Mina, "Hands-on, Discovery, Critical Thinking, and Freshman Engineering," Proceedings of the 2012 ASEE Conference.
2. U. Mohammad, "An Introductory Engineering Course for Freshman Students- From Programming to Implementation," Proceedings of the 2014 ASEE North Central Section Conference.
3. J. J. Marpaung, M. Willcockson, D. Widjaja, and E. Veony, "Using Robotics to Enhance Learning Experience in Classroom," Proceedings of the 2015 ASEE Gulf-Southwest Annual Conference.
4. D.L. Livingston and J.C. Squire, "Robotics in Introduction to Electrical and Computer Engineering at the Virginia Military Institute," Proceedings of the 2002 ASEE Conference.
5. M.Z. Atashbar, D.A. Miller, F. Severance, R. Tanner, and M. Suchowski, "Bridging the Freshman Engineering Gap by Building Mobile Robots," Proceedings of the 2002 ASEE Conference.
6. D. Williams, R. Butera, S. Uluagac, M. Clark, A. Deck, M. Torba, and S. Trahan, "Cooperative University/Industry Development of a Freshman 'Introduction to ECE Design' Course," Proceedings of the 2007 ASEE Conference.
7. LEGO MIDSTORMS, http://www.lego.com/en-us/mindstorms/?domainredir=mindstorms.lego.com
8. 2WD Beginner Robot Chassis V2, http://www.robotshop.com/en/2wd-beginner-robot-chassis-v2-red.html
9. Arduino, https://www.arduino.cc/
10. Entrepreneurial Mindset 101, http://engineeringunleashed.com/#definition
11. NI Multisim, http://www.ni.com/multisim/
12. NI Ultiboard, http://www.ni.com/ultiboard/
13. D.D. Carpenter, K. Hayes, C. Ward, and A.L. Gerhart, "Assessment and Evaluation of a Comprehensive Course Modification Plan," The Journal of Engineering Entrepreneurship (JEE), Vol. 2, No. 2, 2011.