Incorporating Current Technology in an ECE Design Course

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Abstract – In this paper, the authors discuss developments in a second-year design & professional-practice course as part of a four-year “spine” in an engineering program. The course is delivered in two phases—the first with Faculty-wide content and structure, and the second with more discipline-based focus and content. In 2018, the second phase of the Electrical and Computer Engineering (ECE) section of the course was redesigned to introduce a number of selected technical skills from upper-year classes into the second year in order to enhance prerequisite knowledge as a means to sooner and more deeply engage the students in the ECE discipline. This paper discusses incorporating current technology in the development and implementation of the course in the Electrical and Computer Engineering department.

Keywords: Internet of Things, Printed-Circuit-Board Design, Project-based Learning, Electrical and Computer Engineering, Engineering Education, Higher Education.

1. INTRODUCTION

The course discussed in this paper is a second-year fall-term design, professional practice, and communication course within a four-year “spine” [1,2] tailored for ECE students in an engineering program. The course design project was devised to incorporate Internet of Things (IoT) technology as an overarching theme. The project document provided students with a hypothetical scenario where a request was made for consultant teams to research and develop an IoT system for one of three different sites in a hypothetical city. The deliverables of the project were to include technical and communication components that implement the knowledge and skills acquired in the first phase of the course in a real-world application.

As part of the continuous review and improvement efforts in the ECE department, there was a desire to introduce both selected technical skills in lower years as a means of enhancing prerequisites of upper-year courses, and to develop vivid student-engagement in the ECE discipline. The course-teaching team deliberated about the most appropriate skills that align with the course learning outcomes and that may be homogeneously integrated in the course, within a project-based learning environment. The decision was made to introduce printed-circuit-board (PCB) design and implementation, as well as application of the steps of the purchasing cycle.

2. COURSE STRUCTURE

The course was developed as the second in a sequence to build a deep understanding of integrated design, professionalism, and communication skills in engineering students [3]. For the first six weeks of the course all second-year students engage in topical open-ended, complex problems in a collaborative team environment, supported by modular lectures and just-in-time active learning workshops. The content incorporates detailed design methodology and techniques, broad elements of professional practice, as well as oral, written, and presentation communication skill development. For the second six weeks, the students apply this knowledge to a discipline-oriented simulated real-world project, with the intention that students acquire multiple new technical concepts within their discipline while deepening their design, professional, and communication skills.

The course schedule includes two plenary 1-hour lecture sessions and two 2-hour workshop/lab sessions per week in sub-sections of the full class. Most of the lecture sessions in the second phase of the course, were dedicated to introducing new theoretical aspects related to the project topics, whereas the workshop/lab sessions were devoted to practicing technical skills, either as individuals or teams.

2.1. Course Lectures

The theoretical knowledge essential to meet the project objectives were introduced in the lecture sessions and may be grouped into three main themes: (a) innovation and entrepreneurship, (b) wireless communications theories, and regulations and IoT, and (c) PCB design, implementation, and fabrication.

The lectures included innovation and entrepreneurship in engineering; wireless systems: their evolution, regulations, and limitations; IoT and its impact on our lives; and PCB design using an industrial software package. In the lectures, the course instructor invited professional guest speakers from different industries to give the students an insight into their prospective employability in relevant fields of industry. At the end of each lecture, students were asked to reflect on the key take-aways from the lecture. The lab sessions were designed to provide students with the opportunity to practice, under guided assistance, the technical skills required for the course project.

The first lecture introduced innovation and entrepreneurship from the engineering perspective and the potential employers of ECE graduates. The rest of the lectures introduced the main concepts of the project, which include the evolution of wireless and mobile communications, the most current technologies. The pros and cons implicated with wider deployment of these technologies, including the regulatory agencies and documentation that monitors and controls frequency spectrum management. Another concept introduced was IoT and its advantages and disadvantages over preceding technologies. The lectures presented by guest speakers also discussed technical perspectives and challenges of IoT implementation in the real world. The third concept presented in the lectures was the PCB design process, including schematic diagram, circuit layout, component selection, and footprints.

The aim of the project content is to provide students with the chance to mimic some of the experiences that are currently an industry focus. The projects were structured to incorporate “engineering thinking” in terms of how professional engineers might approach these problems, including technical design, environment, cost, compliance of wireless technologies, regulatory bodies and standards, and ethical standards.

This course is scheduled in the first semester of students’ second year after a “general” first year. As such, this is essentially a first exposure to applications in the area of electrical and computer engineering. The course structure, based on the concept of complex, open-ended problem-solving using project-based learning, incorporates individual and team formative feedback from the instruction team as well as peers.

2.3. Lab Activities

The technical skills that students need to acquire to proceed competently in the practical perspective of the course were introduced in four lab activities that support this objective:

Lab 1: Assemble and solder perforated printed circuit boards, integrate multiple circuits, and test connectivity and functionality considering safety procedures.

Lab 2: Set up KiCAD and access the supportive documentation, tutorials, and help. Create a schematic diagram for a simple circuit.

Lab 3: Create PCB layout using KiCAD and generate the manufacturing file.

Lab 4: Construct a basic circuit that includes a 7-segment display controlled by an Arduino and a 74HC595 Shift Register using the Arduino Integrated Development Environment (IDE).

3. PROJECT DESCRIPTION

3.1. Project Objectives

The main objectives of this project are to allow the students: 1) to explore the landscape of wireless communication systems with IoT real-world applications, 2) to attain an understanding of some of the technical design elements; environmental aspects; cost affordability; compliance of different wireless technologies, regulatory bodies and standards; functional/performance specifications; technical and ethical standards, and 3) to gain an insight of different technical aspects that engineers need to consider when dealing with wireless systems, such as hardware, software, management of the frequency spectrum, electromagnetic hazards and compatibility, data security and reliance, interoperability of different technologies, and robustness.

At the end of each lecture, students were asked to reflect on the key take-aways from the lecture. One or two questions were posted for about 30 minutes after the lecture on the learning management system (LMS) in order to assess the level of student engagement and understanding with the material presented. The course instructor analyzed the students’ responses in order to adapt the future lectures and workshop/lab sessions to bridge any gaps.

Due to the time constraint, only a limited number of technical aspects were discussed and presented in the lectures and labs throughout the course. The intention was that the students’ research for the project would inspire a discussion within the teams of the influence of these technical aspects on the proposed design.

3.2. Project Scenario

The project document provides a hypothetical scenario that mimics a real-world Request for Proposal (RFP) in a hypothetical city. It states: “The Corporation of the City of Menofes in Ontario is seeking consultant teams to research and develop an IoT system for three different sites in the city.” The three sites are a mega school, a senior and nursing home complex, and a manufacturing plant that produces and handles industrial gasses. Continuing in the same instructor-defined teams from the first phase of the course, students, are required to determine the needs of potential stakeholders and then design and build a prototype for an application/system/product that may be implemented in one of the three sites, they choose.

3.3. Printed-Circuit Board Design (PCB)

The prototypes designed by the students were all implemented on either breadboards or perforated PCBs. Students were required to develop competency in designing PCBs using KiCAD industrial software.

The software was presented in the lectures, supplemented by guidance for components selection and knowledge of the purchase cycle.

4. COURSE DELIVERABLES AND ASSESSMENT

The deliverables of the course included seven artefacts that are the basis of the course assessment plan, including project proposal, two team project progress reports, an individual PCB design, a team prototype demonstration, a final team project presentation, and a final project report.

The final course grade was aggregated from self, peer, instructor, and judges' assessments, throughout the course. Rubrics for different types of assessment were provided to the students in a timely manner with the appropriate activity.

a) Project Proposal

Each team was required to submit a proposal that included a site selection from the three in the RFP that they would like to work on pertaining to development and deployment of an IOT system. It must include the key aspects of the research to pitch the project ideas. Ideas could be revolutionary or evolutionary/incremental. The proposal must include a clear description of **the problem statement** and its significance to the community considered in the project. It must also encompass an **overall problem definition** that clearly describes the importance of the project, drawing from relevant state of the art research, and guided by the project scope and objectives. **The literature review** included current practices and applications of IoT, relevant wireless technologies and their associated frequency bands, and the limitations and challenges of deploying these systems in the selected site. Teams were required to identify the potential stakeholders in the selected site, list the requirements and needs for an application impacting these stakeholders, and delineate any knowledge gaps to be addressed. A clear description of the application's functionality required to address the stakeholders' needs in the site selected must determine the features and prerequisites of the future proposed solutions. **The project plan** included the design process that will be followed to address the requirements, the key assumptions for the system, and how the solutions to be considered will be evaluated. **The proposal** also had to provide the team's strategy to achieve the project objectives, as well as a brief description of the team's expertise, presented in a team brochure that included the team name and his/her skills and interests.

b) Progress Reports I and II

These brief progress reports, submitted two and four weeks after the proposal respectively, summarized the progress the teams have made since the project's starting date. Each report required discussion and justification of any deviations from the original proposed plan. They also required the current state of the project as related to the proposed schedule with regard to various aspects of the design using a Gantt chart. Each report incorporated explicit mention of whether the work is on schedule, behind schedule, or ahead of schedule. If behind schedule, core issues affecting the project's timeline and the team's mitigation plans had to be discussed.

c) Individual PCB Design Task

PCB design is a global business and a useful skill that is needed by most industries. This technical skill, introduced in the two of the lab sessions, was demonstrated with the PCS deliverable, and assessed with a prototype of limited technical functionality. After the two labs, a survey was administered to obtain insight into the students' understanding and confidence in using the software, and particularly any areas of weakness. As a result of the students' responses, two additional lab sessions were dedicated to provide the required support.

To demonstrate their competence, each student was assigned a circuit diagram of a certain function, and the KiCAD design folder was submitted for assessment. In this task, students were expected to create the schematic diagram and generate a single-layered or a double-layered printed circuit board (PCB) layout, considering the proper footprints in terms of electrical connections and physical dimensions. Due to time constraints students were not required to fabricate this final individual PCB design.

d) Team Prototype Demonstration

Each team was required to demonstrate their technical ideas and the feasibility of their design concepts with a prototype of limited technical functionality

Teams had the liberty to use the appropriate hardware and basic components for the implementation of these prototypes, and were asked to provide a list of needs such as sensors, boards, electronics components, etc. In addition to the components available in the lab inventory, any unavailable components were purchased by the ECE department.

During the demonstration period, teams set up their prototypes and a team representative briefly explained the functionality of the prototype and how it applies to the real world. Two faculty members assessed this task using based on rubric specific to this requirement.

Peer to peer assessment was also incorporated, with each team assessing two other teams with a slightly different rubric.

e) Final Presentation

The final project presentation is a major part of the communication component of the course. In teams, students presented the project idea and the challenges pertaining to the selected site in the project context, design requirements, and process and pathways that led to the final design. Also, they presented the components selection criteria and a brief description of the prototype. Important components of the presentation were the limitations of the prototype designed, as well as future recommendations to mitigate these limitations.

f) Final Report

The technical report was the project's culminating deliverable. Required elements included the overall problem definition, technical design elements, problem solving technique, cost estimation, regulatory compliance considerations, functional and performance specifications, and technical and environmental standards. Students were also asked to describe the intended and actual process to arrive at a final design, with specific reference to how design criteria, health and safety, and economic factors influenced the decision process and final design. Challenges and limitations of the designed prototype and suggestions for future work to broaden and enhance the functionality of the system were also included.

5. STUDENTS' PROJECTS

In spite of the diversity of the sites offered in the Request for Proposal of the project (a mega school, a senior and nursing home complex, and an industrial gas production plant), the students' projects were biased towards the school and the nursing home, which may be attributed to their better acquaintance to the environment in these two sites compared to the production plant. Out of 42 projects, 60% proposed systems for the mega school site, 38% proposed systems for the a senior and nursing home complex, and only 2% proposed systems for the industrial site. For the school sites, the systems developed in the projects solutions ranged from attendance, grading, security, antiterrorism, antibullying, mental health, and lockdown, to learning. The topics chosen in the senior and nursing home complex included security, medication dispensing and control, tracking, biometric monitoring, climate control, fall detection, nutrition, sleep cycles, and emergency evacuation. For the industrial gas production plan, one project proposed a

system that monitored gas leakage from gas cylinders stored in the warehouse.

Conclusions

In this paper the authors present findings from the incorporation of current IoT technology in a second-year ECE Design & Professional Practice Course. The objective was to enhance the engagement of second-year students in the ECE discipline with a technology that signals a new era of wireless communications. As a first exposure to wireless communication and IoT within the ECE program, this new course module was designed to encompass both theoretical and practical aspects of wireless technology through project-based immersion and integrated lectures and hands-on labs. Throughout the project, students applied engineering principles and theories from other disciplinary courses to solve an open-ended problem, considering financial factors, environmental factors, social factors, and public interests in their decision making. They showed an awareness of engineering as a regulated profession, including reference to relevant engineering regulations, and standards, regulatory bodies, and professional associations. Practice, assessment, and feedback on communication skills were integrated throughout the course. Broad open-ended project topics encouraged a wide range of project concepts, some of which may prove to be feasible new technologies in the IoT era.

The end of term student course evaluation showed a high level of satisfaction with the content and implementation of the course, and also provided helpful suggestions to improve content and delivery for the next revision. Anecdotal feedback from several instructors in the second term suggests the knowledge and skills the students acquired in this course enhanced their preparedness for ensuing courses in the second term of the program.

References

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