A Project-based First Year Electrical and Computer Engineering Course: Sensor and Telemetry Systems for High-altitude Balloons

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Jeremy's research is in space physics and electrical engineering, including atmospheric electricity, radio wave propagation, and digital signal processing. He receives external support through grants from agencies such as the US Geological Survey. He has authored more than 25 peer-reviewed publications, often with DigiPen students.

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Christopher Theriault earned his BS in Computer Engineering from DigigPen as the first graduate of the program in 2007. In addition to serving as a Lecturer for the program, he also serves as the Lab Manager for the ECE department, an opportunity which allows him to work with students to develop their projects. His own passions for engineering focus on the embedded system space, and his final student project consisting of a modular electronics platform was used by DigiPen to teach students in the Project Fun programs how to build simple robotics and electronics systems.

Prior to enrollment at DigiPen, he served as the Lead Scenario Designer for Stainless Steel Studios, working on Empire Earth and Empires: Dawn of the Modern World. He continues to develop gaming projects in his spare time. Christopher is also a veteran, having served in the Army from 1991 - 1998 and participated in deployments to Europe and the Middle East.

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Abstract

This paper documents an innovative, project-based 1st-year course in electrical and computer engineering recently developed and implemented at DigiPen Institute of Technology. The primary objective of the course is to engage students in authentic engineering work early in their academic careers. Previous studies have shown that student engagement often leads to increased student retention rates in engineering programs. Moreover, including engineering work in the 1st year of a program often better prepares students for their subsequent and more advanced engineering courses.

The project currently implemented consists of sensor and telemetry systems for high-altitude balloons. Students are required to use the cricketsat design approach, which involves an electric circuit with an output that changes frequency based on properties of the atmosphere. The output of this sensor circuit is then used to amplitude modulate a 433 MHz carrier frequency for long-distance RF communication. The first milestone of the project is to build and test a 555-timer-based cricketsat that measures temperature with a thermistor following a prescribed design. Subsequently, the 555-timer is replaced by a PIC microcontroller (MCU) in the temperature sensing circuit. For the remainder of the project, students work in teams to design their own MCU-based sensor system to measure any property of the atmosphere that changes with altitude, excluding temperature (EM radiation, humidity, wind, pressures, etc.), or instead, they can test an engineering design in the upper atmosphere. Students must make a proposal of their planned project to faculty and peers through an oral presentation and written documents. Once the design is approved, students are required to prototype their design on a breadboard. After testing the prototype, students design, populate, and test a printed circuit board. All of this work culminates with student sensors systems being launched on large weather balloons to about 30 km altitude. In the last few weeks of class, students analyze their data, present their work orally, and write final reports.

In addition to project work, this course introduces students to the basics of the electrical and computer engineering fields. This is done by presenting overviews of diverse subjects such as, but not limited to: the history of electrical and computer engineering, the electronics development cycle, professional ethics, multidisciplinary team environments, and common development tools used in industry. Students are expected to apply this and knowledge from prerequisite and concurrent courses to completing their project.

In our paper, we describe the course in detail, including examples of student projects. Student outcomes related to both technical and soft skills are assessed using student surveys and project evaluation rubrics. We discuss these assessment results and highlight some successes and limitations of the experiential 1st-year course.

Introduction

The traditional model for engineering undergraduate programs in the US is to have mostly foundational courses in science, math, and liberal arts during year 1 of the program[1,2]. Whereas, recent studies have presented evidence that student engagement using active learning methods can lead to increased student retention rates in engineering programs[3,4]. Thus, the model for engineering programs has changed in recent years, with many programs now including engineering courses in the 1st year that often have a design component[5-9]. In this paper, we describe a project-based first-year ECE course at DigiPen Institute of Technology, a university with about 1200 students in Redmond, WA. An assessment of student outcomes is presented and successes and limitations are discussed.

What is project-based learning?

As described by Mills and Treagust[2] and Perrenet et al.[10], many elements make up project-based learning. The most general feature is having open-ended outcomes. This requires student-initiated research, student initiative, strong observational skills, and the application of knowledge in addition to the acquisition of knowledge. Team-based skills such as task and role differentiation are also important, along with good project management ability.

Overview of Computer Engineering program curriculum at DigiPen Institute of Technology

All the Electrical and Computer Engineering (ECE) Department project courses include significant design experience to prepare students for engineering practice. Students are required to take eight project courses, one each semester starting in the first semester of the program. The degree consists of 154 credits over 8 semesters with 17 – 20 credits per semester.

In these courses, students apply knowledge and skills acquired in other courses (e.g., mathematics, physics, computer programming, electronics, and communication) to design, build, program, document, and test interactive embedded devices, such as robotic toys or handheld gaming systems. Working in small teams, students are expected to integrate a microprocessor with various peripheral devices such as storage, input, sensors, and display devices into a portable embedded platform. These projects follow design constraints that are encountered in industry such as use model, cost, power, and portability. Moreover, students are expected to develop team management skills, presentation and documentations skills, and critical design processes, as well as study and implement human-machine interaction.

In addition to the project work, these courses have weekly lectures related to engineering practice. Topics include the history of computer engineering, the electronics development cycle, professional ethics, multidisciplinary team environments, common development tools used in industry, communication and professional skills (e.g., interview preparation, resume/CV writing, and presentations), engineering management, testing and quality control, and statistical methods.

The project courses are designed to support student outcomes that are recommended by ABET. A full description of the program can be found in Thomas et al. 2015[11].

First-year project course description

In ECE 110, CE 1st Year Project, students are exposed to common engineering hardware and software tools (Matlab, SPICE modeling, lab equipment, etc.) and given a project to work on. The project is to develop a sensor and transmitter system that can be deployed on a high-altitude balloon at the end of the semester. They choose from a variety of sensors to use and follow constraints of cost, size, and weight. Thus, their ability to perform design work is furthered. The schematic of the analog sensor circuit is included as Figure 1. The 555-timer in this circuit is replaced by a microcontroller in further iterations of the circuit. This course currently has 8 – 12 students each year.

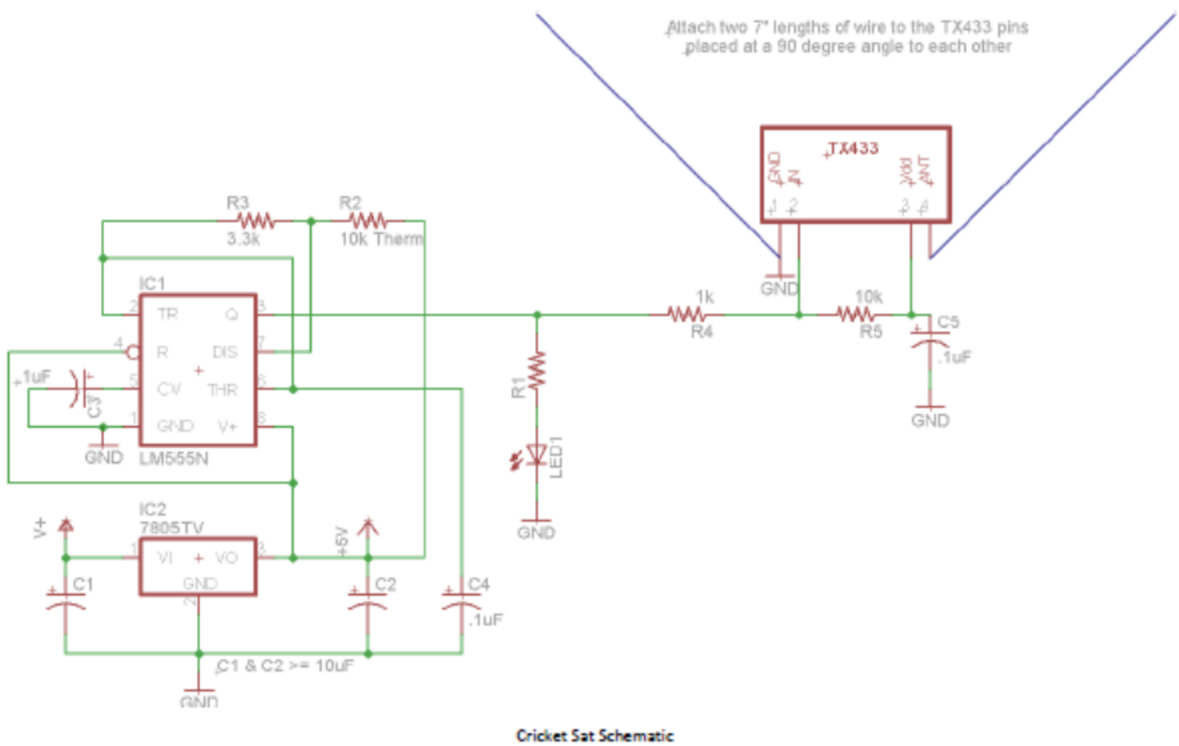

Figure 1: ECE 110 cricketsat thermistor-based temperature sensor circuit.

The lab component of the course requires the students to design and implement a simple analog sensor circuit. The sensor must measure a property of the atmosphere that changes with altitude other than temperature. Examples include pressure, humidity, light and other wavelengths of EM radiation, wind, etc. This continues to build up their practical experience with implementing dc circuits and using test equipment such as multimeters and oscilloscopes. Later in the course students interface their chosen sensors with a microcontroller. The students write their code in the C programming language (although assembly is allowed, if desired). Also, all students are expected to use CAD design tools to create a PCB for their sensor system, which is fabricated for the students to populate. There are two main motivations for this. First, having their system on a PCB instead of a regular solderless breadboard helps to meet the weight requirements for the balloon launch. Second, providing students with early exposure to the PCB design process will improve their efficiency in later projects by minimizing the time required to get a custom PCB up and running. Currently, a student's first attempt at completing a PCB may come in their 3^{rd} or 4^{th} year project when a more complex design is required. In such cases, their project development time is greatly increased. The ECE 110 course was offered for the second time in the Spring 2016 session. The syllabus for ECE 110 is in Appendix C.

Some other universities use high-altitude balloon platforms for introductory engineering and science courses. The Earth and Space Sciences Department at the University of Washington offers Access to Space (ESS 205)[12] and the Aerospace Engineering Sciences Department at the University of Colorado-Boulder offers Gateway to Space (ASEN 1400)[13]. UW ESS 205 is a more basic course than ECE 110 at DigiPen. In ESS 205 students design simple analog sensor systems and the processing and telemetry is handled by systems provided to them by faculty. CU-Boulder ASEN 1400 is somewhat closer in content to the DigiPen course. In ASEN 1400, students design sensor systems that interface with an Arduino microcontroller and Arduino shield that are provided to them. Neither of these other courses requires students to design their own PCBs.

Examples of student projects

During the ECE 110 Spring 2015 session, there were four student groups each working to develop their own sensor platform suitable for launching into the upper atmosphere on a balloon. In order to standardize the interface between the students' sensor packages and the TX433 transmitter used on the balloon, each group was required to route their sensor data through a PIC12F1572 microcontroller. This microcontroller is an 8-pin package. The package includes ADC, PWM, and USART peripherals, but not additional serial communication peripherals such as I^2C or SPI. Most students must limit their choices to analog devices and digital devices that support USART. In addition to developing their sensor circuit, students must also create and populate a PCB to hold their electronics. The PCBs are fabricated through an off-site vendor, which means that students must account for production delays when planning their project timeline. In addition to the on-campus electronics lab used to develop and test their circuits, students also had access to temperature and pressure chambers at the University of Washington in order to simulate conditions in the upper atmosphere. Due to inclement weather the proposed high-altitude launch was postponed until the summer, and most students collected data from a tethered launch instead that took place near the end of the spring semester. A video summary of the high-altitude balloon launch is here: http://news.digipen.edu/academics/ce-students-launch-recover-high-altitude-balloon/#.Vx7ugvkrKJB

Team Free Quincy: Ethan Knoll, Cody Anderson, and Annabelle Pearson

As written in the team's report: "The goal of this project is to build an embedded system capable of relaying information about changes of infrared radiation in the lower atmosphere, and also to measure data from a magnetometer to determine what direction our system is facing. This would be able to tell us which way the light is coming in from."

This project consisted of using a magnetometer and an infrared LED to send light intensity and geomagnetic orientation to the microcontroller for transmission. The magnetometer used two analog voltages to correspond to the orientation of the sensor. The team was able to work out a generalized direction, but when the inputs were close together, their conversion formula produced a discontinuity that caused the output to range between two different sets of values, which can be seen in the blue data of Figure 2. The LED did not work when the students' PCB was populated, so they were only able to receive the direction data during the tethered launch.

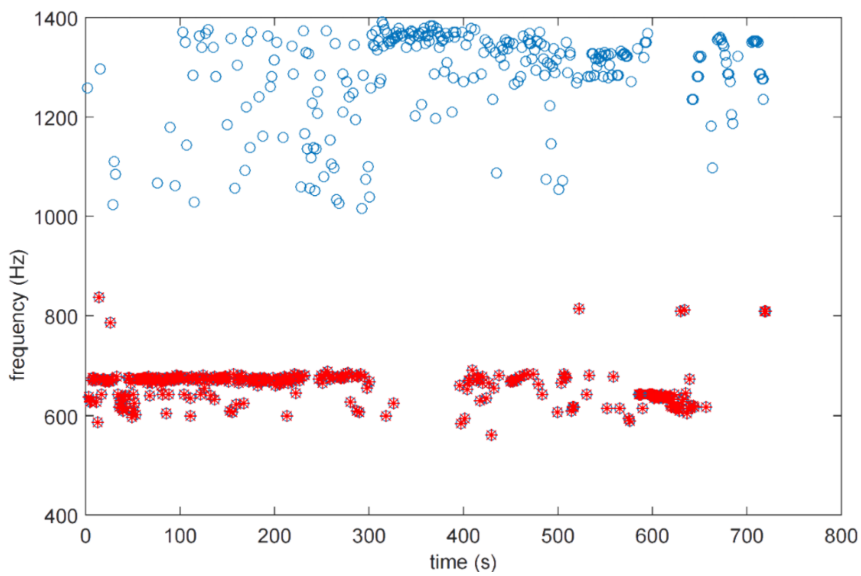

Figure 2: Frequency data from tethered launch

Team SkyHawks: Ryan Winslow, Ben Nollan, and Greg Hall

As written in the team's report: "This projects *(sic)* main goal is to create a balloon payload which will measure pressure and altitude as altitude increases, process the data, and send it to a ground station via a 433 Mhz transmitter. This project is meant to aid in our understanding of embedded circuits, microprocessors, and RF communications. Another goal of this project is to use the altitude of the balloon and pressure measured at that altitude and compare our results to other sources of similar information to gauge the accuracy of our results".

This team was the only one to incorporate a digital communication device into the project, which was a GPS module that communicated via USART. For pressure data, the team used an absolute pressure sensor that produced two analog output voltages. Since the pressure reading mapped to the difference between the two outputs, the team used an operational amplifier to buffer each output, then used a difference amplifier to send a single signal for processing to the microcontroller. The team participated in the tethered launch, but the restricted distance produced little variation in their sensor readings, as can be seen in Figures 3 and 4:

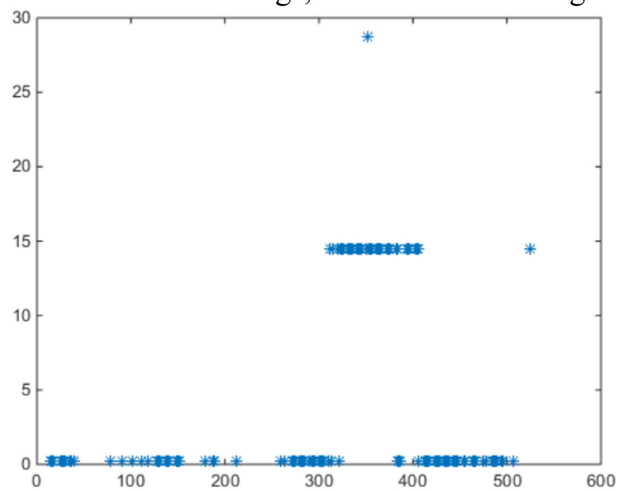

Figure 3: Altitude data in meters (y-axis) vs. time in seconds (x-axis)

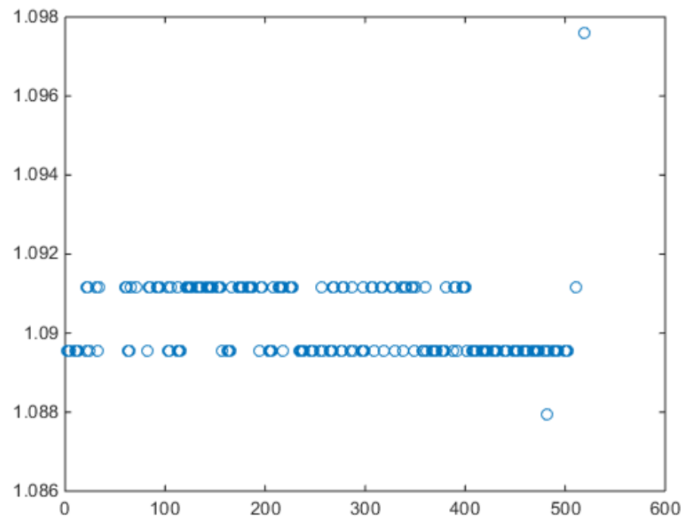

Figure 4: Pressure data in bars (y-axis) vs. time in seconds (x-axis)

Team Kerbal: Keith Tompkins, Andrew Klimentyev, and Al Jay Jackson

As written in the team's report: "In order to study the effects of light pollution within a small-scale area, Team Kerbal has designed a short-distance weather balloon equipped with a photoresistor and thermistor to send information about light in the area to a base station It *(sic)* measures, in lumens, the amount of light indirectly reflected into Earth's atmosphere."

This project relied on the operation of both a thermistor and photoresistor. Since the photoresistor has a varying sensitivity due to temperature, the thermistor data are used to correct for this, but not transmitted to the ground station. This team was able to participate in both the tethered launch and the rescheduled high-altitude launch. During the tethered launch the balloon not travelling a great enough distance to produce a significant variance in the sensor output, as can be seen in Figure 5. This team also discovered problems with some of their circuit components becoming loose or damaged during the flight. As the flight travelled no appreciable distance, the data should have mapped to a nearly straight line, but the physical problems with the circuit caused oscillation in the data values:

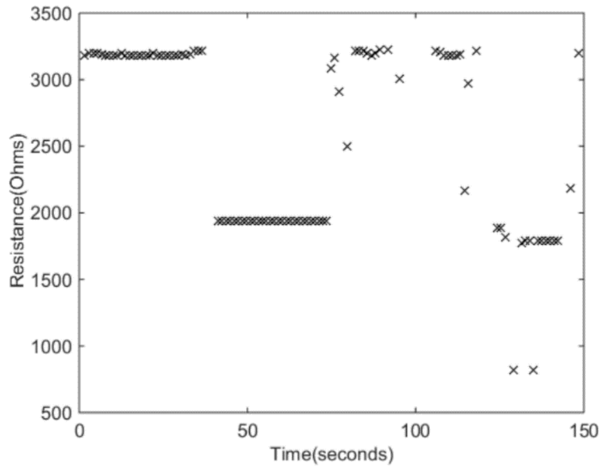

Figure 5: Photoresistance vs. time

Overall, the results were mixed from the various team projects. All teams suffered from the reschedule of the high-altitude launch and were not able to collect much meaningful data. Delays in part acquisition and PCB design prevented most teams from producing a platform they could be confident would work reliably. However, all teams faced at least one major design challenge for which they were able to come up with a creative solution. The teams also developed some initial experience with implementing a project that should prove useful in further project coursework at DigiPen Institute of Technology.

Assessment of student outcomes

At the conclusion of the Spring 2015 and Spring 2016 class sessions, students were given a survey related to the eleven student outcomes promoted by the program and ABET. Survey results are shown in Table 1. Each outcome is associated with several performance indicators that tie to more specific tasks which can be evaluated in some way in the classroom. Students were asked to evaluate on a scale of 1 – 5 (1 = Strongly Disagree, 5 = Strongly Agree) how well these indicators were promoted by the course. Seven of the students in the 2015 course and eleven of the students in the 2016 course completed the survey, with their responses collated and compared below (full survey data are in Appendix B).

Table 1: ECE 110 ABET criteria student survey Spring 2015 and Spring 2016.

DigiPen Institute of Technology, Student Survey Comparison Spring 2015/6

Course: ECE 110 CE 1st Year Project

Student Responses to Survey. Note that 1 = Strongly Disagree, 3 = Neutral, and 5 = Strongly Agree)

	2015		2016	
	Average	Median	Average	Median
Criterion A (an ability to apply knowledge of mathematics, science, and engineering)				
Identify the engineering trade-offs in implementing a solution	3.9	4	3.8	4
Ability to convert the theoretical solution into a hardware implementation	4.0	4	4.0	4
Ability to convert the theoretical solution into a software implementation	4.0	4	3.3	3
Criterion B (an ability to design and conduct experiments, as well as to analyze and interpret data)				
Demonstrate a clear understanding of the Scientific Method and how to test hypotheses	2.9	3	2.9	3
Demonstrate ability to determine and report factors which influence the outcome of the experiment such as errors, accuracy, and uncertainty	3.1	3	3.3	3
Apply statistical methods to test a hypothesis	2.9	3	3.0	3
Perform visualization / data analysis using suitable mathematical and computational tools	3.7	4	3.5	3
Criterion C (an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability)				
Students are prepared to discuss how various project restrictions influenced their design choices	3.9	4	4.0	4
Students are prepared to discuss how their project affects the world at large, such as through societal or environmental impacts	3.0	3	3.2	3
Demonstrate awareness of the ethical practices of product development	2.3	2	3.5	4
Criterion D (an ability to function on multidisciplinary teams)				
Proactive participation in the process of task assignment to team members	3.9	4	4.0	4
Perform the tasks assigned in satisfactory fashion	4.1	4	4.0	4
Able to explain ideas and concepts to team members in an effective fashion	4.0	4	4.1	4
Ability to lead the development effort for the given cycle	3.9	4	4.0	4
Criterion E (an ability to identify, formulate, and solve engineering problems)				

Identify the problem and its constraints	3.9	4	3.8	4
Survey existing approaches to the same problem	3.7	4	3.7	4
Propose a solution and model it using appropriate methods and algorithms	4.0	4	3.6	4
Implement the solution to solve the problem	4.1	4	3.7	4
Validate the solution for correctness and efficiency	4.1	4	3.5	3
Criterion F (an understanding of professional and ethical responsibility)				
Understand the importance of ethics in the workplace environment, including issues like gender/racial discrimination, respect for intellectual property rights, personal responsibility, etc.	2.6	3	3.4	4
Work proactively to avoid plagiarism, and know when to properly attribute the work of others	3.4	4	3.8	4
Demonstrate professional responsibility in areas such as (but not limited to) punctuality, dress, reliability, respect, fairness, etc.	3.0	3	3.8	4
Criterion G (an ability to communicate effectively)				
Communicate an understanding of the underlying theoretical methods	3.8	4	3.7	4
Document processes related to solving engineering problems	3.5	4	3.5	3
Present projects before an audience of peers and faculty	4.0	4	3.9	4
Demonstrate professional communication skills (email, phone, written, workplace best practices)	3.7	4	3.7	4
Demonstrate ability to describe, narrate, analyze and argue persuasively	3.0	3	3.5	4
Demonstrate ability to present research results in a coherent manner	4.0	4	3.6	3
Criterion H (the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context)				
Understand the broader impact of the engineering methods in related fields	3.8	4	3.7	4
Understand the economic and environmental impacts of engineering	3.0	4	3.4	3
Understand the global and societal impacts of engineering	2.7	3	3.4	3
Criterion I (a recognition of the need for, and an ability to engage in life-long learning)				
Understand the theoretical concepts well enough to extend them if necessary	3.4	3	3.9	4
Student demonstrates the solution by using knowledge from multiple courses preceding the current course	3.7	4	3.8	4
Participate in professional organization and societies	3.6	4	3.5	4
Read journal articles and web blogs related to field of				

study; interact with peers	3.1	4	3.5	4
Demonstrate ability to do in-depth, multimedia-based research	2.9	3	3.5	3
Demonstrate ability to communicate with diverse audiences	3.3	3	4.0	4
Criterion J (a knowledge of contemporary issues)				
Understand the relative tradeoffs in engineering solutions	3.6	4	3.9	4
Ability to tailor the solution to fit a practical scenario	3.3	3	3.7	4
Understand the optimization processes, if necessary, to implement a better solution	3.4	3	3.3	4
Ability to choose from a variety of similar approaches to solve the current problem	3.1	3	3.7	4
Read journal articles and web blogs related to field of study	3.3	3	3.5	4
Criterion K (an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice)				
Identify and demonstrate the ability to use the development tools (compilers, libraries) correctly	4.1	4	3.6	4
Use benchmarking tools to analyze the implemented code	3.9	4	3.5	3
Demonstrate ability to use lab equipment such as oscilloscope, functional generator, power supplies, etc.	4.3	4	4.3	4

Given that the typical BSCE student will take this course in their second semester of study, and that none of these performance indicators are expected to be presented at anything more than an introductory level, it might be expected that the average of most responses would tend towards 3/Neutral or even 2/Disagree given the large number of them. This turns out to be the case. Out of the 45 different indicators surveyed, 79% have a 3 – 4 average, while 7% have a 4+ average and only 14% average less than 3. Average and median scores were similar for 2015 and 2016.

Some of the 2015 student comments about the course are as follows:

> "Students need more control over final design."
>
> "I wish I had more knowledge and skills so that I could rebute *(sic)* better in paper or presentation what I'm doing and have more to discuss."
>
> "Nail down guidelines."

Some of the 2016 student comments about the course are as follows:

> "TAs and teachers talk to use like we know way more than we do, which makes feedback and help very confusing."
>
> "We might need more background information on analog side."
>
> "Stop using the PIC as it is."

In addition to the formal surveys, students in the Spring 2016 class were asked to write a letter of advice to the Spring 2017 class. Some comments from these letters are as follows:

> "At first it may seem that what is demanded of you would be something that you may find impossible to deliver but as the semester goes by, you will learn to break down the steps and approach whatever obstacles in the project objectively. You will also learn how to work in teams and how important it is to communicate with your team members and other people that will be able to help you. Do not ever be afraid to ask for help when you are stuck or cannot figure out how to proceed further."

> "After the hump of the first couple weeks are over you'll want to take a little bit of a breather, but I HIGHLY suggest you resist this and begin immediately working on the PWM and ADC, as this is the most difficult part of the course. Also make sure to ask questions when you get confused, but be forewarned that a lot of the answers you receive will be based off of a much higher level of knowledge than you're ready to understand, so don't be afraid to tell fellow students they need to dumb down some of the things they say so that you can fully grasp their advice. "

> "When I started 110, it definitely felt like I had no idea what I was doing. Apparently that is on purpose. What you need to do is ask questions. Ask if stuff is possible. Ask what chip X does. Just start asking. You will find where you need to go. My advice is to always ask questions. Chances are that some other CE student has already done what you're doing, and can help. That or they just know more stuff than you do at this point, and can help. Never stop asking."

Discussion of successes and limitations

There is an implicit acknowledgement in the student feedback that all of the information that a student might find useful in completing their project is not being presented during the lecture portions of the class. This is both a deliberate plan and a natural consequence of allowing students some open-endedness in their choice of project design. It is impossible to plan a lecture sequence that covers all topics a student might require when their ideas are not known at the beginning of the semester. This is also an accurate reflection of their likely experiences in the workplace, where engineers working on innovative projects must perform research and work out for themselves the solutions to their problems. As a 1st-year course, it is a challenge in the planning of the curriculum to strike the right balance between providing students with information and having them discover it for themselves. Project expectations must be kept reasonable, and as can be seen from the above student comments, they are painfully aware of their limitations.

Anecdotally, students are generally unhappy about being asked to implement a project on a "learn as you go" basis. Something that is perhaps not made clear enough to students over the course of the BSCE program at DigiPen Institute of Technology is how much constant learning is a fact of life for professional engineers. This attitude is perhaps reflected in the fact that student outcome B, the "ability to design and conduct experiments, as well as to analyze and interpret data", was perhaps the lowest rated of the eleven criteria for both the 2015 and 2016 groups of students. It is very common for beginning students to run into problems attempting to troubleshoot a system until they have built up a knowledge base from prior experience. The other lower rated criteria generally related to humanities topics such as ethics, communication skills, and the social impact of engineering. It has proven difficult at DigiPen Institute of Technology to present these issues in projects-based courses, as the engineering faculty are not themselves experts in such subject matter, and that too much focus in these areas takes time away from training in project development skills that students value more. It should also be noted that when the original group of 2015 students were asked about their perception of the course one year later, they did have a higher appreciation for its relevance in their project development skills than was apparent at the time they had just completed the course.

Even though student comments often indicate they wish more formal training had been provided in areas like choosing components carefully, hardware troubleshooting techniques, testing, and project development, some of the highest rated categories in the survey are criteria A, D, E, and K, all of which relate to these things. From the results of the student projects, it is clear that criterion E, the "ability to identify, formulate, and solve engineering problems" has been especially relevant as every team encountered and solved some particular problem in their project, even if the final result was that the project did not work as intended. Moving forward, it needs to be made clear to the students that a failed project does not make a failed engineer, but made clear in such a way that students don't take away "we don't need to succeed" as a wrong message.

Faculty workload and project costs are limitations. There are currently three full-time faculty and three full-time staff members available to support the computer engineering students. As the total enrollment of the computer engineering program varies between 14 – 25 students each year, the student-to-faculty ratio is extremely low. Due to the high expectations and demanding workload of the project courses, students rely heavily on the availability of faculty and staff for support. While this does allow the students to be successful, it is a limitation in that is does not easily scale for increased program enrollment. Project costs are another limitation. The main cost for the first-year project course is PCB fabrication, which is typically a few hundred USD per team. Students are not expected to pay for their project supplies out-of-pocket. Indeed, DigiPen Institute of Technology currently does not require students to pay any lab fees to participate in the BSCE program. If the program were to grow in enrollment, lab fees might need to be implemented.

Course changes, implemented in 2016 and proposed for 2017

Minor changes were made to the course for the Spring 2016 session. Changes include the instructor assigning student teams (rather than allowing students to choose their own teams) and starting the PCB design earlier in the term. Based on student surveys, instructor assigned teams were unpopular. However, the instructor noted a benefit of pairing students with varying degrees of background and engineering experience together such that they could learn from each other. In 2015 teams were pressed for time to complete their PCB testing and one team did not get their board to function. Thus, starting PCB design two weeks earlier in the term was beneficial and allowed for teams to have functioning and tested PCBs completed before the tethered test.

Feedback from surveys suggests that implementing ADCs and PWMs on the PIC microcontroller were the most difficult parts of the course for many students. During the 2015 and 2016 courses, students were provided with a document on how to program the PIC and implement a simple ADC. The students were also given the PIC datasheet with relevant sections highlighted. However, students seemed overwhelmed by the complexity of the datasheet and spent many weeks getting their ADCs and PWMs implemented. In 2017, we plan to have to two lab sessions where students work on ADC and PWM with the PIC, these labs will include more detailed instructions as well as support from instructors and TAs.

Conclusion

This paper describes an innovative, project-based first year computer engineering course that involves sensor systems for high altitude-balloons. Students work in teams to design their own MCU-based sensor system to measure a property of the atmosphere that changes with altitude or tests an engineering design in the upper atmosphere. Students propose their project through an oral presentation and written documents. After revising their proposed work based on peer and faculty feedback, students prototype, design, populate, and test a PCB sensor system.

The course was generally successful in that students received experience working on many aspects of authentic engineering design and implementation in their first year of study. That said, the project was a challenge to most students, especially implementing the ADC and PWM features on the PIC MCU. We plan to help alleviate these problems by adding additional, focused PIC labs. Although most student projects did not fully work as initially designed, each team faced at least one major design challenge that was solved independently and creatively.

We will continue to survey students as they proceed through the program on their experiences in ECE 110, and how the course influences later courses. Overall, we feel that the benefits of the course outweigh the limitations and plan to continue to offer revised versions of it in each Spring term.

The conference presentation will also include student projects from the Spring 2016 offering of the course.

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Appendix A: Photos of students sensor systems.

Figure A1: Team FreeQuincy's system

Figure A2: Team Skyhawk's system

Appendix B: Full survey results

DigiPen Institute of Technology, Student Survey Spring 2015

Course: ECE 110 CE 1st Year Project

Student Responses to Survey. Note that 1 = Strongly Disagree, 3 = Neutral, and 5 = Strongly Agree)

	CE, 2014	CE, 2014	CE, 2014	CE, 2014	CE, 2014	CE, 2014	RTIS, 2013	Average	Median
Criterion A (an ability to apply knowledge of mathematics, science, and engineering)									
Identify the engineering trade-offs in implementing a solution	4	3	3	4	4	4	5	3.9	4
Ability to convert the theoretical solution into a hardware implementation	5	3	4	4	4	4	4	4.0	4
Ability to convert the theoretical solution into a software implementation	5	3	3	4	5	4	4	4.0	4
Criterion B (an ability to design and conduct experiments, as well as to analyze and interpret data)									
Demonstrate a clear understanding of the Scientific Method and how to test hypotheses	4	3	1	3	3	4	2	2.9	3
Demonstrate ability to determine and report factors which influence the outcome of the experiment such as errors, accuracy, and uncertainty	3	3	4	2	3	5	2	3.1	3
Apply statistical methods to test a hypothesis	3	3	2	2	3	4	3	2.9	3
Perform visualization / data analysis using suitable mathematical and computational tools	4	3	2	4	5	4	4	3.7	4
Criterion C (an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability)									
Students are prepared to discuss how various project restrictions influenced their design choices	4	3	3	4	4	5	4	3.9	4
Students are prepared to discuss how their project affects the world at large, such as through societal or environmental impacts	3	3	2	2	3	3	5	3.0	3
Demonstrate awareness of the ethical practices of product development	3	3	1	2	2	3	2	2.3	2
Criterion D (an ability to function on multidisciplinary teams)									
Proactive participation in the process of task assignment to team members	3	3	4	4	5	5	3	3.9	4
Perform the tasks assigned in satisfactory fashion	4	4	4	4	5	4	4	4.1	4
Able to explain ideas and concepts to team members in an effective fashion	4	4	4	4	4	5	3	4.0	4

Ability to lead the development effort for the given cycle	4	4	4	3	3	5	4	3.9	4
Criterion E (an ability to identify, formulate, and solve engineering problems)									
Identify the problem and its constraints	4	3	4	3	4	4	5	3.9	4
Survey existing approaches to the same problem	4	3	3	3	4	4	5	3.7	4
Propose a solution and model it using appropriate methods and algorithms	3	3	4	4	4	5	5	4.0	4
Implement the solution to solve the problem	4	3	4	4	4	5	5	4.1	4
Validate the solution for correctness and efficiency	4	3	4	4	4	5	5	4.1	4
Criterion F (an understanding of professional and ethical responsibility)									
Understand the importance of ethics in the workplace environment, including issues like gender/racial discrimination, respect for intellectual property rights, personal responsibility, etc.	3	2	1	2	3	3	4	2.6	3
Work proactively to avoid plagiarism, and know when to properly attribute the work of others	4	4	1	3	3	4	5	3.4	4
Demonstrate professional responsibility in areas such as (but not limited to) punctuality, dress, reliability, respect, fairness, etc.	3	4	1	2	4	3	4	3.0	3
Criterion G (an ability to communicate effectively)									
Communicate an understanding of the underlying theoretical methods	4		4	2	4	4	5	3.8	4
Document processes related to solving engineering problems	3		4	2	3	4	5	3.5	4
Present projects before an audience of peers and faculty	3		5	3	4	4	5	4.0	4
Demonstrate professional communication skills (email, phone, written, workplace best practices)	3		4	3	4	3	5	3.7	4
Demonstrate ability to describe, narrate, analyze and argue persuasively	3		1	3	1	5	5	3.0	3
Demonstrate ability to present research results in a coherent manner	3		4	3	4	5	5	4.0	4
Criterion H (the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context)									
Understand the broader impact of the engineering methods in related fields	4		2	4	4	4	5	3.8	4
Understand the economic and environmental impacts of engineering	4	2	1		4	3	4	3.0	4
Understand the global and societal impacts of engineering	4	2	1	3	1	3	5	2.7	3
Criterion I (a recognition of the need for, and an ability to engage in life-long learning)									
Understand the theoretical concepts well enough to extend them if necessary	4	2	3	3	4	3	5	3.4	3
Student demonstrates the solution by using									

knowledge from multiple courses preceding the current course	3	2	4	4	4	5	4	3.7	4
Participate in professional organization and societies	4	3	2	3	4	5	4	3.6	4
Read journal articles and web blogs related to field of study; interact with peers	4	2	1	2	4	4	5	3.1	4
Demonstrate ability to do in-depth, multimedia-based research	3	3	4	2	2	4	2	2.9	3
Demonstrate ability to communicate with diverse audiences	3	3	2	2	4	5	4	3.3	3
Criterion J (a knowledge of contemporary issues)									
Understand the relative tradeoffs in engineering solutions	3	2	4	2	4	5	5	3.6	4
Ability to tailor the solution to fit a practical scenario	3	3	2	2	4	5	4	3.3	3
Understand the optimization processes, if necessary, to implement a better solution	3	3	2	3	4	4	5	3.4	3
Ability to choose from a variety of similar approaches to solve the current problem	2	3	2	3	4	4	4	3.1	3
Read journal articles and web blogs related to field of study	2	3	4	2	2	5	5	3.3	3
Criterion K (an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice)									
Identify and demonstrate the ability to use the development tools (compilers, libraries) correctly	4	3	4	4	4	5	5	4.1	4
Use benchmarking tools to analyze the implemented code	4	3	1	5	4	5	5	3.9	4
Demonstrate ability to use lab equipment such as oscilloscope, functional generator, power supplies, etc.	4	3	5	4	4	5	5	4.3	4

DigiPen Institute of Technology, Student Survey Spring 2016

Course: ECE 110 CE 1st Year Project

Student Responses to Survey. Note that 1 = Strongly Disagree, 3 = Neutral, and 5 = Strongly Agree)

	CE, 2014	CE, 2015	CE, 2015	CE, 2015	CE, 2015	CE, 2015	CE, 2015	CE, 2015	CE, 2015	CE, 2015	CE, 2015	Average	Median
Criterion A (an ability to apply knowledge of mathematics, science, and engineering)													
Identify the engineering trade-offs in implementing a solution	4	4	2	4	5	3	4	3	5	5	3	3.8	4
Ability to convert the theoretical solution into a hardware implementation	4	5	3	4	4	4	4	3	4	5	4	4.0	4
Ability to convert the theoretical solution into a software implementation	3	3	3	3	3	4	4	2	4	4	3	3.3	3
Criterion B (an ability to design and conduct experiments, as well as to analyze and interpret data)													
Demonstrate a clear understanding of the Scientific Method and how to test hypotheses	4		2	4	3	3	3	3	3	3	1	2.9	3
Demonstrate ability to determine and report factors which influence the outcome of the experiment such as errors, accuracy, and uncertainty	4	2	2	3	5	4	3	3	3	5	2	3.3	3

Apply statistical methods to test a hypothesis	3		2	2	4	3	3	4	3	4	2	3.0	3
Perform visualization / data analysis using suitable mathematical and computational tools	4	3	3	3	4	3	4	4	3	5	2	3.5	3
Criterion C (an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability)													
Students are prepared to discuss how various project restrictions influenced their design choices	5	5	2	3	5	4	4	3	4	5	4	4.0	4
Students are prepared to discuss how their project affects the world at large, such as through societal or environmental impacts	4	1	2	3	5	3	4	2	4	5	2	3.2	3
Demonstrate awareness of the ethical practices of product development	4		2	4	5	4	4	2	4	3	3	3.5	4
Criterion D (an ability to function on multidisciplinary teams)													
Proactive participation in the process of task assignment to team members	5	3	3	4	5	5	4	4	3	4	4	4.0	4
Perform the tasks assigned in satisfactory fashion	5	4	3	3	5	5	4	3	3	5	4	4.0	4
Able to explain ideas and concepts to team members in an effective fashion	5	4	3	4	5	5	4	3	3	5	4	4.1	4
Ability to lead the development effort for the given cycle	5	4	3	3	5	5	4	3	3	5	4	4.0	4
Criterion E (an ability to identify, formulate, and solve engineering problems)													
Identify the problem and its constraints	4	4	3	4	5	4	4	3	4	4	3	3.8	4
Survey existing approaches to the same problem	3	4	3	4	4	3	4	4	4	5	3	3.7	4
Propose a solution and model it using appropriate methods and algorithms	3	4	3	4	4	4	4	3	3	5	3	3.6	4
Implement the solution to solve the problem	3	4	3	4	4	4	4	3	3	5	4	3.7	4
Validate the solution for correctness and efficiency	3	4	3	2	5	3	4	3	2	5	4	3.5	3
Criterion F (an understanding of professional and ethical responsibility)													
Understand the importance of ethics in the workplace environment, including issues like gender/racial discrimination, respect for intellectual property rights, personal responsibility, etc.	4	1	3	3	5	3	4	2	4	4	4	3.4	4
Work proactively to avoid plagiarism, and know when to properly attribute the work of others	3	3	3	3	5	4	4	3	5	5	4	3.8	4
Demonstrate professional responsibility in areas such as (but not limited to) punctuality, dress, reliability, respect, fairness, etc.	3	3	3	3	5	4	4	3	5	5	4	3.8	4
Criterion G (an ability to communicate effectively)													
Communicate an understanding of the underlying theoretical methods	3	3	3	4	5	4	4	3	5	5	2	3.7	4
Document processes related to solving engineering problems	3	4	3	4	4	4	3	3	2	5	3	3.5	3
Present projects before an audience of peers and faculty	4	4	3	4	4	3	4	3	5	5	4	3.9	4
Demonstrate professional communication skills (email, phone, written, workplace best practices)	4	3	3	4	5	2	4	3	5	4	4	3.7	4
Demonstrate ability to describe, narrate, analyze and argue persuasively	4	1	3	4	4	4	3	3	5	5	2	3.5	4
Demonstrate ability to present research results in a coherent manner	4	3	3	4	4	3	3	3	5	5	3	3.6	3

Criterion H (the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context)													
Understand the broader impact of the engineering methods in related fields	4	3	3	4	5	4	4	3	5	4	2	3.7	4
Understand the economic and environmental impacts of engineering	4	3	3	3	5	3	5	2	2	5	2	3.4	3
Understand the global and societal impacts of engineering	5	3	2	3	5	3	5	2	3	4	2	3.4	3
Criterion I (a recognition of the need for, and an ability to engage in life-long learning)													
Understand the theoretical concepts well enough to extend them if necessary	5	3	4	4	5	4	5	3	4	3	3	3.9	4
Student demonstrates the solution by using knowledge from multiple courses preceding the current course	5	3	3	3	4	4	5	3	4	4	4	3.8	4
Participate in professional organization and societies	4	4	3	2	3	2	5	3	4	5	4	3.5	4
Read journal articles and web blogs related to field of study; interact with peers	4	4	3	2	4	3	5	3	4	5	2	3.5	4
Demonstrate ability to do in-depth, multimedia-based research	3	4	3	2	3	3	5	3	5	5	2	3.5	3
Demonstrate ability to communicate with diverse audiences	5	4	3	2	5	3	5	3	5	5	4	4.0	4
Criterion J (a knowledge of contemporary issues)													
Understand the relative tradeoffs in engineering solutions	3	4	2	3	5	4	5	3	5	5	4	3.9	4
Ability to tailor the solution to fit a practical scenario	3	4	2	3	5	3	5	3	4	5	4	3.7	4
Understand the optimization processes, if necessary, to implement a better solution	3	4	2	2	4	4	2	2	4	5	4	3.3	4
Ability to choose from a variety of similar approaches to solve the current problem	4	4	2	2	5	3	4	3	5	5	4	3.7	4
Read journal articles and web blogs related to field of study	4	4	3	2	4	4	4	3	3	5	2	3.5	4
Criterion K (an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice)													
Identify and demonstrate the ability to use the development tools (compilers, libraries) correctly	4	1	3	3	5	4	3	4	4	5	4	3.6	4
Use benchmarking tools to analyze the implemented code	3	3	3	3	5	3	5	3	4	5	1	3.5	3
Demonstrate ability to use lab equipment such as oscilloscope, functional generator, power supplies, etc.	5	3	3	5	4	5	5	4	4	5	4	4.3	4

Appendix C: Course syllabus

Teams
Teams consist of two people and are chosen by the instructor.

Sensor-system constraints

- The system must measure a property of the atmosphere that changes with altitude other than temperature. Examples include pressure, humidity, light & other wavelengths of EM radiation, wind, etc. Or instead, they can test an engineering design in the upper atmosphere. For instance, how does a motor perform in the upper atmosphere.
- Systems must be approved by the instructor.
- The entire system must weigh less 1 lb.
- The system must use a PIC 12F1572 microcontoller and a TX433 transmitter.
- The system must be prototyped on a breadboard and/or solder board.
- The final version must use a custom designed printed circuit board (PCB).
- Systems must be tested using a detailed test plan.
- The system must be functional in order to fly on the balloon.
- The entire cost of the system must not exceed $100 (excluding the cost of the PCB).

Project proposal
Each team must give a proposal presentation during week 3, and submit a written proposal during week 4. Guidelines, rubrics, and examples will be posted to the class website.

Tethered launch
The tethered launch is during week 12 from a local park.

Moses Lake launch
Students who are available during the third week in in May are encouraged to launch their payloads on larger balloons to 30 km altitude as part of a field trip to Moses Lake, WA.

Final paper and presentation
Each team must submit a final paper during week 14 and give a final presentation during week 15. Guidelines, rubrics, and examples are posted on the class website.

Table 1: Weekly course breakdown

Week	Lecture Topic (Mondays)	Project Work (Wednesdays)
1	What is a Computer Engineer?	Basics of the atmosphere / Thermistor 555 cricketsat
2	Project conception/ Technical presentations / Technical writing in LaTex	Basic analog circuits/ Thermistor 555 cricketsat complete
3	Holiday, no classes	MCU cricketsat / Sensor proposal presentations due
4	Basic analog circuits and SPICE	MCU cricketsat / Sensor proposal papers due
5	RF Communications	MCU cricketsat complete / Design sensor

6	PCB design with EAGLE	Design and build sensor / PCB design
7	Holiday, no classes	Build and test sensor / PCB design
8	More circuits and RF	PCB design complete
9	Calibration and Testing	Populate and test PCB
10	Intro to complex functions & signals	Test PCB
11	Data analysis in MATLAB	Test sensor system
12	N/A, Prep for balloon flight	Tethered balloon flights
13	Data analysis in MATLAB	Data analysis / Final reports
14	N/A, Work on final reports	Final reports due
15	N/A	Final Presentation

Grade breakdown

- Homework and Quizzes 15%
- Presentations (Initial & final) 15%
- Written reports (Proposal & final report) 30%
- Weekly reports and evaluations 10%
- Technical review and evaluation by instructor 30%