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PAPERS

Teaching Ocean Discovery through Technology to Non-Engineering Majors

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Abstract
Humans have been exploring the ocean for thousands of years, but it wasn't until the early 1800s when systematic ocean exploration began. In the present day, scientists and engineers make use of modern technology to explore the ocean. Because the ocean affects all people, the ocean can be a great means to enhance public awareness of modern technology through describing the technology used to make important ocean discoveries. In this paper, we present our first implementation of a university course for non-engineering majors called "Ocean Discovery through Technology." The goal of our course was to enhance a non-engineering student's awareness of and excitement about technology. Students learned about modern ocean sensors (e.g. conductivity, temperature, depth, pH, turbidity, sonar, and radar), sensor platforms (e.g. research vessels, drifters, gliders, ROVs, AUVs, piers, satellites) and data analysis tools (e.g. Excel™, Matlab™, R, Google Earth™) through hands-on laboratory activities, field trips, and student presentations. Based on course evaluation feedback, we believe our course was successful in enhancing a student's exposure to and excitement about technology and therefore plan to continue to improve upon and offer more sections of this course to our student body in the future.

Introduction

Humans have been exploring the ocean for thousands of years (starting with the first record of sea going vessels by the early Egyptians in 4000 BCE), but it wasn't until the early 1800s when systematic ocean exploration began. In the present day, scientists and engineers from the academic community, federal agencies, state governments, and the private sector make use of modern technology to make new ocean discoveries that affect the air we breathe, the food we eat, the medicine in our cabinets, the jobs some have, and the sports some play. Because the ocean affects all people, the ocean can be a great means to enhance public awareness of modern technology through describing the technology used to make important ocean discoveries.

In this paper, we present our first implementation of a university course for non-engineering majors called "Ocean Discovery through Technology." Ocean Discovery through Technology was the first class to be offered in the new Marine Science (MSCI) curriculum within the Department of Biological Sciences at California Polytechnic State University in San Luis Obispo, CA (Cal Poly). The class is an upper-division elective that contributes to the Technology Area of the General Education (GE) requirements that all non-engineering Cal Poly students must fulfill (Cal Poly General Education Program, 2015). Non-engineering, upper-division students from any department who satisfy the basic math prerequisite are eligible to enroll. Appendix A provides a list of academic majors represented in this first edition of the class.

A variety of instructional methods were employed with the goal of enhancing awareness of and excitement about technology in all students despite their disparate academic interests. Emphasis was placed on active learning techniques, (defined as "involving students in doing things and thinking about the things they are doing" (Bonwell & Eison 1991)) which took the form of student presentations, field trips and laboratory assignments, (some in the form of games). Active learning has been shown to promote excitement and enhanced learning in the classroom (Meyers & Jones 2003). In addition, educational games have been shown to provide students with a motivating and stimulating environment while providing them with immediate feedback to promote learning (Bodnar et. al, 2015). Student feedback concerning exposure to and excitement about technology was positive but, as with any first-time teaching experience, potential improvements and enhancements have been discussed.

We present a description of the class beginning with a brief overview including a topic outline. Thereafter, the students' experience in the class is described in three sections: student presentations, field trips and labs. The fifth section summarizes student responses to the field trips and laboratories followed by the instructors' conclusions upon completing the first quarter offering. Finally, a "future directions" section presents comments about the intended evolution of the class.

Course Overview

We co-taught our "Ocean Discovery through Technology" course for the first time during the 10-week spring quarter 2015. The course consisted of 30 non-engineering students representing 18 different majors (see Appendix A). The course met every Monday and Wednesday from 7:40am-9am for lecture and either Monday or Wednesday (14 students met Monday, 16 students met on Wednesday) from 9:10am-11am for an activity. The lectures mostly consisted of a brief discussion of the previous week's activity, a broad overview of the weekly topic with practical examples and some preparation for the upcoming activity. We also had a guest lecture on the CalWave project to highlight current research at Cal Poly on ocean wave energy harvesting. On the weeks where we had field trips, we canceled the lecture to use the time for the field trip. The students in the Monday activity met for the field trip on Monday from 7:40-11am and the students in the Wednesday activity met for the field trip on Wednesday from 7:40-11am. We selected an early morning time to allow for better weather conditions for ocean-related field trips (the sun is typically not as hot and the wind is not as strong in the morning). Table 1 below shows the topics discussed and activities conducted each week in the 10 week quarter. Note that we conducted two student presentations, three field trips, and five laboratory activities.

Table 1: 10-week Course Schedule

Week	**Topic**	**Activity**
1	History of Ocean Technology	*STUDENT PRESENTATIONS*: Current Ocean Related Topic
2	Uses of Ocean Technology	*FIELD TRIP*: Cal Poly Pier

3	Ocean Sensors	*LAB*: Sensors in a Bucket
4	Data Sampling and Visualization	*LAB*: Matlab Data analysis
5	Uses of Ocean Technology	*FIELD TRIP*: Cayucos Abalone Farm
6	Ocean Sensor Platforms	*LAB*: AUV Navigation
7	Real-Time Telemetry	*LAB*: Telemetry Games
8	Uses of Ocean Technology	*FIELD TRIP*: Morro Bay kayaking
9	Remote Sensing	*LAB*: Remote Sensing in Matlab and Google Earth
10	Topics of Interest	*STUDENT PRESENTATIONS*: Final Project

In the following sections we describe in some detail the presentations, field trips, and lab activities conducted in this course.

Student Presentations

In order to learn more about our students and their interests, we started the class activity section with student presentations. Students were asked to individually research a current ocean related topic and give an informal 3-5 minute oral presentation about the topic and why it was of interest to them. Topics included El Nino, whale migrations, artificial reefs, shark finning, the "garbage patch", ocean acidification, and OTEC (Ocean Thermal Energy Conversion) to name a few. It was our hope that students would then relate the technology described throughout the course to their topic of interest and see how technology could improve (or hinder) human understanding of that topic.

The final student presentations, given in groups of 1-3 during the last week of the course, consisted of a more fully researched ocean-related topic (which could have or could have not been the same topic presented during the first week of class). These 8-10 minute presentations were to include the history of the topic and a statement about why we should think it is important followed by a more detailed discussion about the technologies that were used to gain knowledge about the topic. It was our hope that by the end of the course (when the students gave the final group presentations), they would feel more comfortable discussing the technology having learned about different ocean-related technologies during the past 9 weeks.

Field Trips

In order for students to see ocean technology in action, we took them on three field trips: the first to the Cal Poly Pier, the second to the Cayucos abalone farm and HF Radar site, and the third to the Morro Bay estuary and oyster farms. Below we describe the activities conducted during each field trip.

Cal Poly Pier

Our first field trip visited the Cal Poly Pier (Figure 1). Our location in San Luis Obispo, CA affords Cal Poly students unique and convenient access to the Pacific Ocean. Starting in 2001, the industrial crude oil transport pier in nearby Avila Beach was converted to a Cal Poly facility for marine research and education. It includes numerous sensors for both oceanography and meteorology, a flowing sea-water system and headquarters for scientific boating and diving programs. After a safety briefing and an overview of the upcoming activities, the students divided into four groups and visited four distinct stations in turn.

Figure 1: Cal Poly Pier (North up) with close-up in inset lower right

The first station comprised a tour of the pier facility. The students were introduced to the facility superstructure, the two sea-going vessels, the water-level dive platform and the various ongoing research projects all within the perspective of the benefits of associated technology. The highlighted project was the live seawater aquariums fitted with simulated tide, temperature and sunlight cycles as well as automated nutrient dispensation.

The second station provided an exercise representing low-visibility navigation led by the pier diving safety officer. After a description of the scientific diving program headquartered on the pier, the group divided into buddy pairs for the exercise. Protected from obstacles by one member, the other member of each pair had general visibility reduced to zero with a towel over his/her head and traversed a prescribed loop course using only a compass. The distance from the actual end point to the desired end point was measured and recorded. The activity was then repeated with the roles reversed.

At the third station, the students used Niskin bottles to collect water samples from three different depths off the south edge of the pier. Using the dimensions of the pier relative to the seabed and the local tide table, the students determined where to place the Niskin bottle on the deployment line. Each sample was decanted to a bucket for a temperature measurement and thereby the students collected a coarse profile of temperature with depth.

The fourth station occurred at the automated pier profiler on the NW corner of the pier. The students were introduced to the instruments included on a multi-sensor cage that is lowered to the bottom and retrieved every 30 minutes. The students were shown the LabVIEW™ program that controls the profiler operations and viewed plots of the live data that were collected during the cast that they witnessed. They also reviewed plots from previous casts to learn about variability and how the data are representative of actual changes in the ocean.

Cayucos Abalone Farm / HF Radar Site

Our second field trip was the Cayucos Abalone Farm and HR Radar Site (Figure 2). After the whole group attended a comprehensive tour of the abalone farm, the students divided into two groups to learn about the HF RADAR deployed by Cal Poly next to the abalone farm to measure ocean surface currents and some simple meteorological instruments.

Figure 2.Aerial view of The Abalone Farm, Inc. north of Cayucos, CA

The tour of the abalone farm traversed the entire facility except for the sterile laboratory used for egg handling. The tour was arranged to follow the life cycle of the abalone from spawning through the stages of development to harvest-size adults. The technologies encountered by the students were numerous and mostly involved in the extraction, use and disposal of fresh seawater. Other technologies included offshore kelp harvesting, nutrient management and distribution as well as culling and transfer of abalone to larger tanks as they grow. The description of the HF RADAR site focused on the advantages of understanding coastal ocean surface currents and the effort required to maintain sensors and electronics that are exposed year-round to the coastal environment. The demonstration of the meteorological instruments explored the variation of incident sunlight with the seasons, the time of day and the angle of the photovoltaic sensor relative to the incoming rays. Measurements made by the students included temperature, relative humidity, incident solar radiation, wind speed and wind direction.

Morro Bay Estuary / Oyster Farms
Our third and final field trip was to the nearby Morro Bay tidal estuary which provided an optimal setting for a novice kayaking experience. The students undertook a round trip paddling excursion of less than 5 km total distance. While on the bay, they visited both of the resident oyster farms and, at one of them, were given a friendly tutorial on oyster farming technology and aquaculture in general.

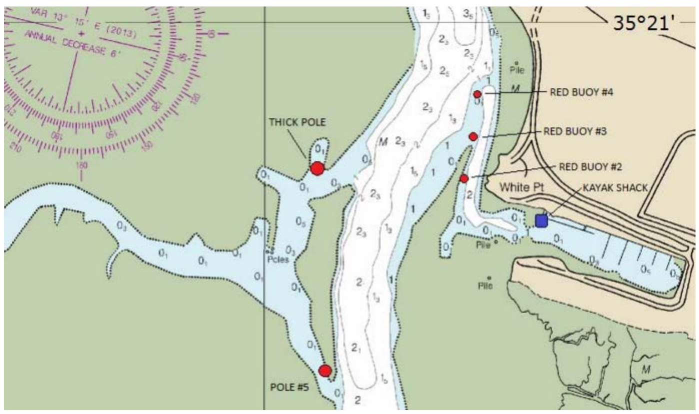

Figure 3: Kayaking Map of the Morro Bay Estuary

The farthest point of the excursion was Cal Poly's remote meteorology station, a solar-charged, battery–powered suite of sensors with wireless data uplink to campus. The students saw close at hand the effects of biofouling on sensors deployed in a salt water environment. While paddling, the students took turns using a handheld depth finding sonar and learned about UTC time, tides, the effects on surface vessels of wind and tidal currents and waypoint navigation. Figure 3 shows a section of the kayaking map given to students.

Labs
In order for students to practice using instruments, platforms, and data analysis tools, we conducted five laboratory experiments: Sensors in a bucket, Matlab Data analysis, AUV Navigation, Telemetry, and Remote Sensing in Matlab and Google Earth. Below we describe these laboratory activities.

Sensors in a Bucket
For the "Sensors in a Bucket" lab, the students divided into three groups and visited three distinct 'stations' each with a different oceanographic sensor placed in a bucket of water. The three sensors included a Sea-Bird Electronics 37-SIP MicroCAT Conductivity, Temperature &

Pressure Monitor (CTD), a WetLabs ECO-FLNTU Fluorometer & Turbidity Sensor (ECO); and an Aanderaa 3835 Oxygen Optode (OXO). At each station, the students practiced setup (powering on the instrument and connecting a serial cable between the host computer and instrument), configuration, operation, data collection and preliminary analysis with the instrument.

For the CTD, the students operated the instrument in both fresh water and sea water, with and without ice to observe the changes in temperature and salinity read out by the instrument. For the ECO, the students operated the instrument in both fresh water and sea water and held different colored leaves in front of the sensor to excite the fluorescence response in the chlorophyll. They learned about calibration coefficients used to convert raw sensor ADC counts to engineering units. Finally, for the OXO, they used a small aquarium bubbler to increase the oxygen concentration and saturation percentage, added ice to drop temperature then ran the bubbler again. They were able to observe how cold water can hold more dissolved oxygen than warm water and how fresh water can hold more dissolved oxygen than salt water.

For preliminary data analysis, students made Excel charts of collected data and compared and contrasted their data sets from the changing variable experiments. They were also asked to observe instrument response time and magnitude to changing conditions.

Data Analysis

For the Data Analysis lab, students received an introduction to importing, plotting, and performing some data processing techniques in Matlab. The students first obtained a time series oceanographic data set from the Central and Northern California Ocean Observing System website (CeNCOOS, 2015). CeNCOOS is part of a national framework of integrated coastal observing systems covering all coastal areas throughout the United States. They then imported that time series into Matlab and plotted the data. From the plot, the students were able to observe outliers in the data set and times in the record where no data were collected. They were taught how to remove outliers and select ‘good’ portions of the time series record for further analysis.

Students then analyzed their ‘good’ record of data by finding its min, max, mean and standard deviation. They also plotted a histogram of the data, its FFT, and a 4, 12, and 24 hour moving average of the data set. They were asked to consider if the data made sense based on their understanding of the oceanographic variable they were considering (i.e. does temperature rise during the day and fall at night? does the tide rise and fall twice a day? etc.).

AUV Navigation

For the AUV Navigation lab, students were asked to ‘act’ as an Autonomous Underwater Vehicle. Autonomous Underwater Vehicles follow a given ‘mission’ (a set of waypoints) using a GPS and compass (and other instrumentation), collecting data along their track, and possibly collecting additional specific data at the given waypoints. Students divided into four groups and were asked to download two applications on their cell phones: GPS Status (for navigating by compass and GPS coordinates) and MyTracks (for recording their track). Each group was given a set of three waypoints (GPS coordinates around campus) as their 'AUV Mission.' Prior to executing their mission, students performed calculations on paper to determine the distance between and compass heading to each waypoint. Upon executing the Mission, students were asked to take a picture of at each waypoint, and to locate a hidden object (a geocache) at the second Waypoint. At the end of the Mission, students were asked to download their track and compare it with the intended mission. They observed how it is often difficult to travel in a straight line as there are obstacles in the way. They also observed how it is important to have a very accurate GPS when trying to find a small object at a specific location.

Telemetry Games

For the Telemetry Games lab, students explored sending and receiving information using different encoding and decoding schemes and observed how errors in transmission can occur each time information is encoded and decoded into different forms. Telemetry involves getting information from a remote source to a remote destination wirelessly. Information at the source must be encoded to be prepared for transmission and then signals must be decoded at the receiver for receipt of the sent information. Each time the information changes form, errors in transmission can occur. The students practiced four encoding and decoding schemes including natural language, Morse Code, Frequency Shift Keying, and pictorial images. For each of the messages they transmitted to their partners, they calculated their speed of transmission and the error rate (either in words, characters, or bits per minute) at the receiver. The students then made plots of transmission speed and error rates and saw a general trend that the faster the transmission the higher the error rate. They introduced a competition to see who could transmit a message the fastest with the lowest error rate.

Remote Sensing in Matlab and Google Earth

For our final lab, students practiced remote sensing techniques in Matlab and Google Earth. For the Matlab activity, they downloaded a LandSat file (a satellite image file comprised of 8 spectral bands) of the coast of San Francisco. The students were asked to generate a true color (combining spectral bands 2, 3, and 4) and SWIR (shortwave infrared - combining spectral bands 2, 4, and 7). Then then made use of these images to identify different land types (water, soil, forest, urban areas, etc.) (Wende, 2015). They finally created a rudimentary classifier to classify the image into the different land types and calculate the percentage of that land type in the image.

For the Google Earth activity, students were first asked to explore the shape of the sea floor and describe the patterns of seafloor bathymetry across the globe. They were asked to explain the reasons for large continental shelfs in some areas and lack thereof in other areas in terms of plate tectonics. Secondly, they were asked to make use of Google Earth's polygon tool and altitude settings to determine the effect of 1m, 5m, and 10m sea level rise on a coastal town of their choice.

Assessment

In order to assess the effect of our course on a student's exposure to and excitement with technology, we asked students to provide a written reflection about each field trip and lab activity. The reflections were overwhelmingly positive and often highlighted the excitement involved with doing something new for the first time or having the chance to have a truly hands-on experience with technology. Table 2 below summarizes the reflections based upon 1. the exposure the activity gave students to new technology and/or new experiences and 2. a student quote that was representative of most of the student comments.

Table 2: New exposure and representative student quotes for each activity

Activity	**Exposure (out of 30 students)**	**Quotes**
FIELD TRIP: Cal Poly Pier	24 students had never been to the Cal Poly Pier	*"This field trip was amazing. It opened my eyes the practical uses of all of the technology we have/will learn about."*
LAB: Sensors in a Bucket	25 students had never worked with oceanographic sensors 16 students had never made a graph in Excel	*"This is a very hands on experience which is beneficial to students because that way they can see it in person and better understand the technology."*
LAB: Matlab Data analysis	24 students had never used Matlab.	*"Before this class, I had never used Matlab. I now have a general grasp of how the software works and how useful it is when someone was to graph and plot data."*
FIELD TRIP: Cayucos Abalone Farm and HF Radar Site	28 students had never been to the Abalone Farm or HF Radar site. Several students had not yet seen an abalone.	*"I have always been interested in wind and weather and was greatly interested in learning about some technology, albeit not as advanced as the most recent gadgets, used to measure their various characteristics."*
LAB: AUV Navigation	25 students had never navigated by GPS coordinates and a compass before	*"It was enjoyable in the sense that it allowed us to use math in a meaningful way that is used in real- world marine technology. I never really did an activity in which the Pythagorean Theorem would be useful in an applicable situation. This inspired me to create lesson plans that are interactive the way this lab was for my future classroom."*
LAB: Telemetry	29 students had never been exposed to details of encoding and decoding schemes (Morse code and FSK) before	*"Seeing the whole class beeping and booping at each other was quite a foreign experience as almost no other class would ever have you do it, but very entertaining to be sure. I would highly suggest repeating this activity for both the entertainment and academic value."*
FIELD TRIP: Morro Bay kayaking	15 students had never been kayaking before	*"Overall, the kayaking expedition in the bay was a great experience. I think it was very beneficial especially for real-time interaction with tidal flux. Feeling the ebb and flow of the tide was wicked awesome. It was a great opportunity to learn about local oyster aquaculture firsthand and be able to compare it with the Cayucos abalone farm. I believe this is a fun and exciting*

		way of experiencing information and data collection that we have been introduced to in class and apply our knowledge firsthand."
LAB: Remote Sensing in Matlab and Google Earth	25 students had never worked with satellite images before	*"I became really interested to learn more about the predictions of sea-level rise after seeing how much of my home town would be underwater if the sea-level rose by 5m."*

Based on student feedback, we believe the course was successful in enhancing awareness of and excitement with technology among non-engineering students. The student quotes capture how the active learning techniques truly made the topics presented "fun and exciting." Field trips were engaging because of their variety compared to a classical classroom/lab experience. They provided students with a chance to get out in the fresh air and sunshine and experience how the technology they learned about in class was being used in the real-world. Laboratory assignments were engaging because of the component of teamwork and the element of fun associated with those labs presented in the form of games (e.g. Telemetry games and AUV geocaching). Finally, based on the quote from the student concerning the Telemetry Games lab, our class opened the eyes to a future K-12 school teacher on how to make science, technology, engineering and math relevant and fun for students.

Future Directions

Due to the success of the course, the Biological Sciences Department intends to offer more sections of the course to more students. However, running multiple sections of field trips throughout the year can be time prohibitive for those volunteering to lead tours and hands-on field activities (see acknowledgements). Therefore, in order to reach the goal of making the course available to more students while keeping the active learning component that has proven so successful, we intend to restructure to course to include more hands-on lab activities in lieu of field trips. We also hope to incorporate more brief guest lectures to provide increased exposure to the numerous ocean-related research projects underway at Cal Poly and elsewhere nearby on the central coast of California (MBARI, UCSC, UCSB, CeNCOOS, etc.). Finally, we plan to leverage our experience with the design and implementation of the Ocean Discovery through Technology class that is offered to all non-engineering majors to create a highly technical class specifically geared toward the new marine science majors.

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Appendix A – List of Academic Majors Represented in the course (30 students)

Anthropology and Geography (ANG)
Art (ART)
Animal Science (ASCI)
Biology (BIO)
Biomedical Engineering (BMED)
Business (BUS)
Communication Studies (COMS)
Economics (ECON)
English (ENGL)
Earth Science (ERSC)
Graphic Communication (GRC)
Journalism (JOUR)
Kinesiology (KINE)
Landscape Architecture (LARC)
Liberal Studies (LS)
Mathematics (MATH)
Nutrition (NUTR)
Physics (PHYS)

Supporting K-12 Engineering Instruction through University Outreach

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Abstract
The Next Generation Science Standards [NGSS] are new science education standards for students in grades K-12 that are beginning to be implemented across the United States. The inclusion of engineering in science instruction is perhaps the biggest difference between the NGSS and earlier standards and will have important implications for engineering departments at higher education institutions. First, because this is a new goal for science instruction, K-12 teachers will need support integrating engineering into their instruction. Engineering departments can help support teachers by providing outreach to K-12 schools. Undergraduate and graduate engineering students who participate in providing outreach to K-12 schools also benefit. Second, it will eventually change the background engineering knowledge of entering freshmen. In this paper, we present an overview of the NGSS, discuss ways engineering faculty can support K-12 teachers and their own university engineering students through outreach, and suggest how the background engineering knowledge of entering freshmen will be impacted by implementation of the NGSS.

Introduction
The Next Generation Science Standards [NGSS] (NGSS Lead States, 2013) have been developed with the goal of changing the way K-12 science is taught in the U.S. The NGSS differ from previous reforms by (1) incorporating engineering concepts and practices into science instruction, (2) presenting a three-dimensional framework of disciplinary core ideas, cross-cutting concepts, and science and engineering practices, and (3) presenting standards as knowledge-in-use performance expectations that combine all three dimensions (Krajcik, Codere, Dahsah, Bayer, & Mun, 2014). The inclusion of engineering in science instruction is perhaps the biggest difference between the NGSS and previous reform documents and has important consequences for undergraduate engineering faculty. Firstly, K-12 teachers will need support to successfully implement engineering principles and practices in their classrooms. Engineering faculty can support K-12 by providing outreach to K-12 schools. Secondly, successfully implementing the NGSS in K-12 classroom will result in beginning college students who have experienced engineering education prior to entering college. This will likely change the entry knowledge base of entering engineering freshmen, necessitating changes in the undergraduate curriculum. As such, the inclusion of engineering in the K-12 standards suggests a vital role that engineering faculty can play in K-12 classrooms.

Many K-12 science teachers lack experience with engineering and engineering instruction. Only 14% of high school and 7% of middle school science teachers have completed one or more engineering courses in college (Banilower et al., 2013). University outreach to K-12 schools can support these teachers in meeting the demands of the NGSS. Even before the publication of the NGSS, many engineering departments had already begun implementing outreach programs in their local communities in response to the need for increased numbers of engineering graduates. Engineering faculty members and students are involved in larger curricular efforts such as the FIRST robotics competition (www.firstinspires.org), Purdue's EPICS K12 initiative (engineering.purdue.edu/EPICS/k12), TeachEngineering curriculum for K-12 teachers (www.teachengineering.org), and the Boston Museum of Science program Engineering is Elementary® (www.EiE.org). In addition, there are numerous examples of local efforts at a myriad of universities as highlighted in ASEE's K-12 Division meetings each year. Programs include STEM field trips (Innes, Johnson, Bishop, Harvey, & Reisslein, 2012), single day engineering outreach events run by undergraduate engineering students (Pickering, Ryan, Conroy, Gravel, & Portsmore, 2004; Widmann, Self, & Schuster, 2015), and middle school robotics curricular materials (Usselman, et al., 2015). Some of these programs are targeted efforts to help teachers and students meet the demands of the new standards, while others are designed primarily to increase interest and awareness of engineering as a career choice.

In this paper, we present an overview of the NGSS and discuss how engineering faculty can support K-12 teachers through outreach in ways that also support their own graduate and undergraduate students. We also discuss how the new standards may require changes to undergraduate engineering curricula.

Engineering and the NGSS

As pointed out by Brophy, Klein, Portsmore, and Rogers (2008), in the current climate of education, the "E" in STEM tends to be de-emphasized or ignored altogether. Children have a natural inclination to design and tinker and this should be capitalized on through the incorporation of engineering in primary school (Lachapelle & Cunningham, 2014). As such, there is a growing body of research looking at how students do engineering, how they understand it, and how to best teach them (e.g., Capobianco, Diefes-dux, Mena, & Weller, 2011; Carroll, 1997; Rogers & Portsmore, 2004). In an effort to increase engineering in the K-12 curriculum, *A Framework for K-12 Science Education* [Framework] (National Research Council [NRC], 2012) was drafted in 2012 based upon guiding principles for engineering education from the National Academy of Science (Katehi, Pearson, & Feder, 2009). This framework helped shape the NGSS that have now been adopted by many states, including California. A significant change in these standards is the inclusion of engineering practices and goals at all levels of K-12 schooling.
The guiding principles for K-12 engineering education laid out by the National Academy of Science (Katehi et al., 2009) are as follows:

1. K-12 engineering education should emphasize engineering design
2. K-12 engineering education should incorporate important and developmentally appropriate mathematics, science and technology knowledge and skills
3. K-12 engineering education should promote engineering habits of mind (p. 4-5).

The Three Strands of the NGSS

The NGSS describe what children in grades K-12 should be able to do at the conclusion of specific grade levels. These standards are written as *performance expectations* that draw on three types of knowledge: (1) disciplinary core ideas, (2) science and engineering practices, and (3) crosscutting concepts. For example, one performance expectation at the third grade level is, "Ask questions to determine the cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other." This performance expectation includes a science and engineering practice ("ask questions"), a crosscutting concept ("cause and effect relationship"), and a disciplinary core idea ("electric and magnetic interactions"). The NGSS includes engineering at the K-12 level in three ways: (1) as part of the science and engineering practices, (2) as disciplinary core ideas, and (3) integrated into performance expectations. These three ways are detailed below.

Science and Engineering Practices

The NGSS specify eight science and engineering practices (Table 1) that should be incorporated into science instruction at all grade levels to "[support] a better understanding of how scientific knowledge is produced and how engineering solutions are developed" (NRC, 2012, p. 41). Students should be learning engineering (and science) through these practices as well as learning about these practices.

Table 1. *Science and Engineering Practices from the NGSS*

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Disciplinary Core Ideas

In addition to the practices, the NGSS specify disciplinary core ideas for engineering design that should be taught alongside the science content. These "Engineering Design Standards" (see Table 2) are focused on the parts of the engineering design process, but get incrementally more complex throughout the grades.

Table 2. *Engineering Design Standards from the NGSS*

	Kindergarten – 2nd Grade
K-2-ETS1-1	Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.
K-2-ETS1-2	Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.
K-2-ETS1-3	Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.
	3rd – 5th Grade
3-5-ETS1-1	Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
3-5-ETS1-2	Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
3-5-ETS1-3	Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.
	Middle School
MS-ETS1-1	Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
MS-ETS1-2	Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
MS-ETS1-3	Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
MS-ETS1-4	Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

High School	
HS-ETS1-1	Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
HS-ETS1-2	Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
HS-ETS1-3	Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
HS-ETS1-4	Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

Performance Expectations

As mentioned, in the NGSS, the standards are written as performance expectations. Each performance expectation integrates science and engineering practices, disciplinary core ideas, and crosscutting concepts. Some of the performance expectations for life science, physical science, and earth and space science also have engineering applications. The examples of performance expectations discussed below show how children are expected to develop engineering competency over their K-12 education.

With the NGSS, engineering at the lower elementary school level will be more fundamental and emphasize the basic engineering design process through having students tinker and explore while conducting investigations into science content. For example, a physical science performance expectation at the Kindergarten level (K-PS2-2) asks students to "analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull" (NGSS Lead States, p. 5). They give an example of students creating a course (including ramps and other structures) that a marble could move through, turn, and knock down other objects. This would help students demonstrate understanding of a physical science disciplinary core idea while simultaneously engaging in the engineering design process.

At the upper elementary school level, the engineering design standards get slightly more complex by adding constraints that students need to think about in the first part of the process, having students develop multiple solutions in the second part, and asks that students think about how to improve designs in the final part. The science performance expectations also get more complex, which allows for students to engage in more complicated engineering tasks. For example, an earth and space science standard about Earth and Human Activity (4-ESS3-2) asks students to "generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans" (NGSS Lead States, p. 36). They give an example of students designing earthquake resistant buildings, which could demonstrate understanding of the science content standard and the engineering design process. This could also be an opportunity for students to learn more engineering-specific content while designing and building and could potentially connect to multiple science standards.

In middle school, the engineering design standards get much more complex and add more abstract factors for students to think about through the process, including impacts on people and the environment that may limit possible solutions, as well as developing a model of their solution that they can test. In addition, the iterative nature of the engineering design process is now being emphasized in these standards. Many performance expectations that incorporate engineering ask that students build physical objects which they can use to do tests to evaluate whether their design solution works. For example, a physical science standard about energy (MS-PS3-3) asks students to "apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer" (NGSS Lead States, p. 57). They give an example of students designing and building an insulated box to keep food cold or a solar cooker. Each of these examples allows for multiple possible designs and allows students to test and optimize these designs since they are constructing physical models.

At the high school level, the engineering design standards emphasize the identification of a real-world problem that can be solved using the engineering design process. They also ask that you take into account a wider range of constraints, but that you prioritize these depending on which is more important. Lastly, they ask that modeling be done using computer simulations that can more accurately predict impacts on multiple factors. The examples given in the NGSS are more true to what engineering in the field would look like including designing more effective football helmets to minimize force on collision, learning about different materials at a micro- and macroscopic levels and capitalizing on the traits of materials in a design solution, designing a renewable source of energy by converting one type of energy to another, and designing solutions to minimize human impacts on the environment through technology and other means.

These types of activities suggested in the NGSS take into account all aspects of the standards (disciplinary core ideas, science and engineering practices, and crosscutting concepts), but also allow students to learn about multiple types of engineering in the process (materials, environmental, and chemical just to name a few). The integrated nature of the NGSS has the potential to expose students at the K-12 level to many science and engineering concepts and applications.

Outreach

While the NGSS set ambitious goals for including engineering in science instruction, many K-12 science teachers lack experience with engineering and engineering instruction. Through outreach to K-12 schools, college and university engineering departments can help K-12 teachers incorporate engineering into their science teaching. Universities often develop outreach programs with local K-12 schools to advance mutual goals of improving education (James et al., 2006; Tanner, Chatman, & Allen, 2003; Williams, 2002). In other words, these outreach programs not only have the potential to improve K-12 education, but can improve university education as well. Studies have documented positive impacts of science outreach on K-12 students and teachers such as increased interest in science for students and improved content knowledge for teachers (Laursen, Liston, Thiry, & Graf, 2007; Williams, 2002). Studies have also documented positive impacts for undergraduate and graduate students who provide the outreach. Participating in K-12 outreach is an opportunity for undergraduate and graduate students to interact with children and engage in science and engineering instruction. Outreach can make science and engineering more attractive to undergraduates, improve their science and engineering content knowledge, and develop their teaching and communication skills (Gutstein, Smith, & Manahan, 2006; Rao, Shamah, & Collay, 2007; Williams, 2002).

Because engineering is new to K-12 standards, there are many more well-documented reports of science outreach programs that address K-12 standards than reports of engineering outreach programs. So, we use reports of science outreach programs and discuss how research on science learning through outreach can be harnessed to develop and implement engineering outreach programs that result in increased learning for the K-12 students *and* the university participants. Specifically, in this paper, we will discuss various types of science outreach programs and the impacts of these programs on the graduate and undergraduate student participants who provide the outreach. Then we will suggest recommendations for designing outreach programs that maximize benefits and minimize risks for these university participants.

Types of K-12 Outreach Opportunities

Outreach programs can be described by the context, the duration of the intervention, and whether the program has a course or training component (Laursen et al., 2007; Williams, 2002).

Context. We identified two main *contexts*, or locations, of outreach interventions in the literature. These include (1) programs that provided direct classroom enhancement in the K-12 classroom during class time, and (2) programs that provided informal science activities (e.g., out-of-class or afterschool programs) (Rao et al., 2007; Williams, 2002). Outreach programs in which undergraduate and/or graduate students work in K-12 classrooms to support science instruction may be called direct classroom enhancement (Williams, 2002), a "scientist in the classroom" model (Laursen et al., 2007), or a scientist-teacher-student partnership (Peker & Dolan, 2012). In these types of programs, university students might give presentations, assist teachers with science instruction, or partner with teachers to develop and implement activities. The most common roles for the participants are assisting teachers in conducting labs, leading small group activities in class, and performing demonstrations (Grant, Liu, & Gardella, 2014). In contrast, in programs that provide informal science activities, undergraduate and/or graduate students interact with K-12 children in out-of-school contexts such as afterschool programs or family science nights. For example, Rao et al. (2007) reported on an undergraduate science club that organized and hosted family science nights. In a service-learning course evaluated by Gutstein et al. (2006), undergraduates had opportunities to lead weekly science activities with families in a community-based program for English-language learners or to lead activities in an after-school program.

Duration. The second distinguishing characteristic is the *duration* of the intervention (Laursen et al., 2007). Short-duration interventions involve one or a few sessions per classroom or group. For example, Laursen et al. studied a program that was considered a short-duration program because the presentations were one-time events for various classrooms. Long-duration interventions were described as providing more sustained involvement in one classroom or group. For example, in another program, graduate students partnered with the same teachers throughout the academic year to develop and implement curricular units (Stamp & O'Brien, 2005).

Support for providers. A third distinguishing factor is support for the outreach providers. Some outreach programs have trainings, seminars, or courses for the university participants. In some cases, the outreach programs may also be considered to be service-learning courses (Cone, 2012; Gutstein et al., 2006; Rao et al., 2007). Alternatively, outreach programs might have trainings, seminars, or supplementary courses for the university participants. For example, programs have offered training institutes to acquaint participants with teaching methods before starting outreach, seminars for participants to discuss and share their experiences, and sessions throughout the academic year that cover topics such as pedagogy and classroom management (Laursen et al., 2007; Page, Wilhelm, & Regens, 2011; Stamp & O'Brien, 2005).

Impacts on University Participants (Outreach Providers)

Impacts on graduate students. Much research on university outreach participants has focused on graduate students, in part, due to former NSF Graduate Teaching Fellows in K-12 Education (GK-12) Program. Studies of GK-12 outreach programs, as well as other outreach programs involving graduate students, have found that graduate students benefitted from improved communication skills, increased science content knowledge, personal gains such as a sense of accomplishment, and clarified career options. Graduate students also improved their science teaching skills as well as their understanding of teaching and education (deKoven & Trumbull, 2002; Laursen et al., 2007; Page et al, 2011; Stamp & O'Brien, 2005; Thompson et al.; 2002).

Although there have been many reported positive impacts, graduate students have experienced various tensions from participating in GK-12 programs (Table 3). For example, Thompson et al. (2002) found that graduate students thought there was no difference between doing science and teaching science, while the K-12 teachers they worked with thought the graduate students lacked experience with science teaching. Graduate students also encountered professional risks such as loss of standing in their research lab and setbacks in their own research. These professional risks stemmed from the time commitment for outreach and competing foci between their research and the GK-12 program.

These are challenges specific to the academic demands of graduate students. The benefits and risks of participating in science education outreach may differ for undergraduates. For example, undergraduates do not have the research demands that graduate students have. Undergraduates who participate in science education outreach may face different obstacles and reap different benefits. As such, examining the impacts of participating in outreach on undergraduate participants is important.

Table 3
Impacts of Outreach Programs on Graduate Students Identified in the Literature

Positive Outcomes	Negative Outcomes and Obstacles
• Communication Skills • Teamwork • Collaboration • Content Knowledge • Increased Confidence • Science Teaching Skills • Awareness of Issues facing K-12 education	• Tension between outreach and research work • Lack of advisor support • Loss of standing in research group

Impacts on undergraduate students. Although connecting graduate student scientists with K-12 teachers and students is a common outreach model, outreach programs also use undergraduate students to provide K-12 outreach and the undergraduate participants can benefit from the experience (Williams, 2002). Based on survey and interview data, Rao et al. (2007) found that undergraduates from three outreach programs learned to integrate scientific information across disciplines, increased their understanding of science concepts, and increased their confidence in sharing scientific knowledge. According to Grant et al. (2014), undergraduates reported improved science communication skills from participating in science outreach. Like the graduate students, undergraduates have also experienced career impacts such as clarified career choices and the development of transferable professional skills such as communication, leadership, teamwork, and organization (Carpenter, 2015; Gutstein et al., 2006; Rao et al., 2007).

Other reported outcomes are unique to undergraduates. Rao et al. (2007) found that increased exposure and access to faculty and university resources was an important benefit to undergraduates. The opportunity to work with other undergraduate students from different science disciplines and the opportunity to work with children were also cited as positive impacts. Undergraduates can also learn about science teaching and learning. For example, Gutstein et al. (2006) described and evaluated a service-learning course and concluded that the course plus outreach provided the undergraduates with an authentic and participatory experience to learn about teaching and learning science. Similarly, Carpenter (2015) found that undergraduate science majors developed important ideas about science teaching and learning by participating in outreach. These ideas included accessing students' prior knowledge, engaging students in science practices, and relating science concepts to students' interests and experiences.

Outreach Program Elements and Recommendations

Reviewing the literature reveals common program elements that may increase positive impacts on university participants. Common program elements from the literature include associated trainings or courses in pedagogy, the type of intervention, the duration of intervention, and involvement of university faculty and collaboration among departments. From these elements we make recommendations about the design of engineering outreach programs.

Recommendation 1: Include training for the university participants. Designing an outreach program with a training or course component better prepares undergraduate and graduate students to interact with K-12 students. Courses or seminars before and/or during participation in the outreach program can enhance the teaching skills, knowledge about teaching and learning, and understanding of issues affecting K-12 education that undergraduate and graduate students gain from participating in outreach. University students participating in outreach have an opportunity to apply course material in real instructional contexts, reference their outreach experiences as they learn material during the course, and reflect on their experiences with other participants.

For example, in the program studied by Laursen et al., (2007), formal training contributed to skill development as participants applied ideas in real classroom situations and analyzed and discussed them afterward. Other outreach programs were in the form of service-learning courses. For example, in the service-learning course evaluated by Gutstein et al. (2006), undergraduates were introduced to contemporary educational theories and methods during a weekly seminar and then applied what they learned during weekly outreach opportunities. Participants in service-learning courses reported that course components were useful and applicable, and outreach components provided opportunities to apply skills and knowledge in real classrooms or instructional situations (Gutstein et al., 2006; Rao et al., 2007).

Recommendation 2: Consider direct classroom enhancement model if schedules allow and informal outreach if scheduling is more difficult. The direct classroom enhancement model of outreach is particularly beneficial for university students since they can observe and interact with K-12 teachers (Laursen et al., 2007; Moskal & Skokan, 2011; Stamp & O'Brien, 2005). When university students performed outreach in K-12 classrooms, the classroom teachers were leveraged as curriculum and pedagogy experts, and were especially helpful in providing instructional approaches appropriate for age and diversity (Moskal & Skokan, 2011; Peker & Dolan, 2012; Stamp & O'Brien, 2005). STEM undergraduates participating in outreach felt that support from the classroom teacher was necessary to fully develop science communication skills (Grant et al., 2014). Through outreach, university students have also gained a greater awareness of the K-12 system including the limited time allocated to science, lack of resources, and importance of university K-12 outreach (Page et al., 2011). However, scheduling was a common problem for undergraduates participating in direct classroom enhancement programs since K-12 class times are during the day when undergraduates also have classes (Rao et al., 2007; Williams, 2002). Providing outreach in informal science settings may be easier for undergraduates to schedule. For examples, undergraduates in a science club providing informal outreach had fewer issues with scheduling than undergraduates participating in classroom-based outreach (Rao et al., 2007).

Recommendation 3: Consider carefully whether a long-duration or short-duration model will work best for your goals. Long- and short-duration models of outreach can benefit university participants. Graduate students in a short-duration, distributed model program reported that by presenting in a wide-range of classrooms and grade levels, they learned to quickly adapt their teaching to different audiences and increased their own understanding of science content by having to explain and demonstrate scientific concepts to various audiences (Laursen et al., 2007). In addition, these graduate students reported that the repetition of presenting the same activities in many classrooms helped them improve teaching skills through trial and error, refining their approaches, and observing students. Observing a variety of teachers and teaching styles was also influential (Laursen et al., 2007).

Participants in long-duration programs reported improvements in the breadth of their own science content knowledge because they had to cover many topics while working with one teacher throughout the academic year, including topics that they had not recently used or had little experience with (Stamp & O'Brien, 2005). Sustained classroom experience also exposed university students to issues about culture and learning, relevant pedagogy, the difficulties teachers face, and the importance of resources (Moskal et al., 2007; Williams, 2002). Thus, as engineering faculty develop outreach programs, the types of benefits afforded by short- and long-duration programs and how these benefits align with program goals should be considered.

Recommendation 4: Include faculty in the program. Faculty involvement is an important factor in the success of outreach programs and in experiences for undergraduates. In studies by Carpenter (2015) and Rao et al. (2007), undergraduates considered the opportunities to work with faculty during outreach as particularly beneficial. Since faculty involvement is meaningful to undergraduate participants, as a program is being developed, engineering faculty should be encouraged to participate.

Recommendation 5: Partner with education departments. Williams stressed the importance of collaboration between science and education departments. According to Williams:

> Partnerships with schools of education are perhaps the most critical support resource to develop. Responsible for preparing future generations of teachers, schools of education offer a natural way to connect the science content with the pedagogical training. More than that, partnerships with schools of education give outreach programs a measure of credibility because they represent a potential investment in the community. (pp. 57-58)

Thus, as university engineering departments attempt to design K-12 outreach programs, collaborating with university education departments should be prioritized.

Considering the Next Generation of Engineering Undergraduates

Currently, most freshmen entering their undergraduate work have very little understanding or experience with engineering as a discipline. However, as the NGSS are implemented across grade levels, students will enter higher education with increasing knowledge of the discipline of engineering and how it relates to science. College and university engineering departments can link to and build on this knowledge. For example, by the time high school students graduate, they will have engaged in multiple design challenges and be familiar with the engineering design process outlined in the NGSS. As mentioned above, the engineering design process described in the NGSS is essentially (1) define/delimit problems, (2) develop solutions, and (3) optimize the design solution. This process is intended to be general enough to map to many different versions of the engineering design process. As such, college and university faculty can link how they teach the engineering design process to the process freshmen already know. Further, by the time students finish high school, they will have been expected to:

- Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
- Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
- Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
- Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

Knowing these expectations can help college and university faculty build on their freshmen students' prior experiences with engineering. In addition, as described above, K-12 students will be expected to learn science and engineering through the practices of science and engineering. Freshmen will enter college with many experiences engaging in the practices of engineering including defining problems, developing solutions, developing and using models (including prototypes), analyzing data, and communicating ideas.

Conclusion

The inclusion of engineering in the Next Generation Science Standards (NGSS) is an important change in the vision of K-12 science education. These standards are not intended to create a new generation of engineers, but instead to instill an understanding and appreciation for engineering in all citizens. The designed world and the process that engineers engage in to identify problems and create solutions to problems are important goals for *all citizens.* However, the new standards do have the potential to have a significant influence on the next generations of engineers. Successful implementation of the NGSS across the K-12 years will make entering freshmen better prepared to take on the rigors of engineering coursework. It will also ensue that *all* students are aware of engineering as a potential field and, as such, may increase the diversity of entering freshmen. Including engineering faculty and students in collaboration with K-12 teachers to design curriculum and support activities through outreach is vital for such important outcomes. By developing outreach programs that connect university engineering students with K-12 classrooms, engineering faculty can support K-12 engineering instruction and benefit their own university students.

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Inquiry Based Learning Activities: Exploring Newton's 2nd Law

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Abstract
At California Polytechnic State University, San Luis Obispo, hands-on activities are being used to uncover common misconceptions among engineering students in undergraduate engineering dynamics. Once these misconceptions have been determined, Inquiry Based Learning Activities (IBLAs) are developed that prompt the students to question these misconceptions when real systems do not behave in the way they predict. This creates cognitive conflict in the students and an opportunity to repair their misconceptions. Ideally, the IBLAs force the students to determine where exactly their misunderstanding is occurring and fix these misconceptions. With an IBLA, students are asked to predict individually how a physical system will behave under certain conditions. After making these predictions, they join a team to discuss their different perspectives and make any adjustments to their predictions if they have gained new knowledge. After the team discussion, the students are asked to run an experiment with physical hardware and comment on the results. One activity that has been developed is the mass-pulley IBLA which explores Newton's Second Law: F = ma. The hardware for the experiment consists of two different Atwood machines at either end of a rod; an Atwood machine is a pulley with two differing masses at either end and was developed to study constant acceleration. The students release both Atwood machines at the same time and observe which system hits the ground first and therefore accelerates the fastest. There are five distinct cases which explore the effects of varying the total mass and total force of each system. This activity has been performed in multiple classes over a number of quarters. Throughout this time, the activity has gone through several revisions such as adjusting the order of the cases, the number of cases, and switching unit systems. This paper presents an analysis of the effect of the different case order, number of cases and unit change on student understanding to determine the optimal variance that will cement the desired concepts in the students' minds.

Introduction/Background

Dynamics is one of the first classes in the undergraduate engineering curriculum to expose students to challenging real world concepts. This course is made even more challenging due to the many misconceptions that students have developed from observations of everyday life. For example, an apple may fall from a tree to the ground faster than a leaf (although they have the same acceleration in the absence of air resistance) or two football players may collide with thee smaller player getting hurt more often (although an equal force is exerted on both players)(Georgette et al, 2013). Since January of 2013, two faculty members along with a team of undergraduate and graduate engineering students have been developing and testing a set of five different Inquiry Based Learning Activities (IBLAs) that address these important misconceptions in dynamics. Instead of a typical passive learning environment where the professor feeds students the information through lecture, the IBLAs use active learning methods that involve students participating in hands-on activities with their peers in order to better learn the concepts presented. Another goal of these IBLAs is to improve motivation by encouraging the students to interact with their peers and to take charge of their own education.

IBLAs consist of presenting students with a physical situation and asking them to predict what will happen. After the students make their own individual prediction, they join a group and discuss the scenario as a team. The students next investigate the situation by experimenting with physical hardware in a way that is specifically designed to demonstrate unexpected behavior, creating cognitive conflict. The hardware therefore becomes the "authority" rather than the professor, thus forcing students to confront any misconceptions they might have (Widmann et al, 2014). Each IBLA follows the cycle depicted in Figure 1 and somewhat resembles the scientific method of predicting an outcome, observing a real world concept, and explaining the result.

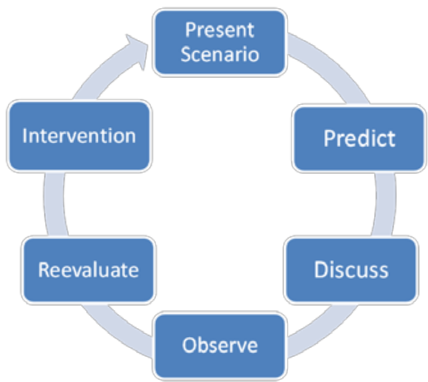


Figure 1. Standard IBLA Cycle

The Mass-Pulley IBLA consists of two Atwood machines, each of which has a string with differing weights on either side of a pulley. A schematic of the two systems is shown in Figure 2. The students are asked to predict which system will accelerate the fastest, as well as to rate their confidence in their hypotheses. After making individual predictions, the students are asked to join teams and discuss their hypotheses. Any new predictions that arise after the team discussion are gathered; students are encouraged to change their prediction if the team discussion has any impact on their original hypothesis. At this point, the students are allowed to run the activity, releasing the weights from rest and observing which weight hits the ground first. Once the students note their findings and discuss with their team why their hypothesis was or was not correct, the instructor provides a brief "intervention" for the students. The intervention allows the instructor to discuss what occurred and to give the students tools to properly analyze the system. For example, in the first case shown below, System A has a total mass of 250 grams and a net force of 50 grams multiplied by gravity. System B also has a net force of 50 grams multiplied by gravity, but a total mass of 450 grams. Typically, prior to the experiment, the students only look at the total force and do not address the total mass. However, once they run the experiment and see how drastically the difference in mass affects the acceleration of each system, they begin to understand the relationship between force, mass and acceleration which is typically represented by Newton's Second Law or F = ma.

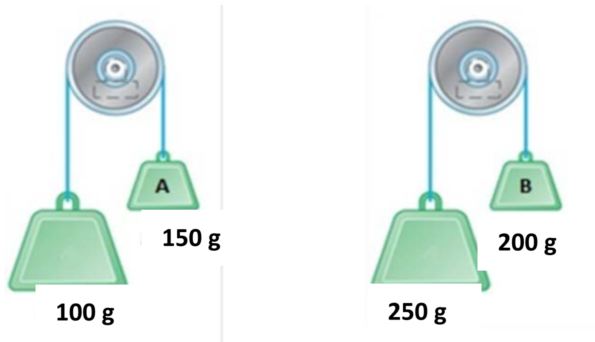


Figure 2. Example Pulley Set Up

This first case explores the effect of varied mass on acceleration if the total force is the same. The succeeding cases then help the students question what will occur if the sum of the masses are the same but the net forces are different, as well as the outcome if both of these properties are varied at the same time. Examples of these cases are shown in Appendix A. Ultimately, it is hoped that at the end of the activity the students have gained the knowledge that mass has an inversely proportional relationship with acceleration, while force has a directly proportional relationship with acceleration, and that the students can use Newton's Second Law to effectively predict the motion of the system (Adam et al., 2015). Another desirable outcome from these activities is for the students to be able to take this newfound knowledge and apply it to a similar concept presented in a different way, which is referred to as a "transfer" problem. In this activity, the last case is used as a transfer problem and is shown in Figure **3**. It is somewhat similar to the other cases; however one of the weights has been replaced by a constant force equal to the weight on the other Atwood machine. Ideally, the students should be able to recognize that a force is massless and therefore System A is much lighter and therefore has a quicker acceleration. Although this part of the activity is dubbed a "case", the students are only able to complete the "hypothesize" and "discuss" portion of the IBLA cycle due to the difficulty in creating a physical system with an observable constant force. Instead of running a physical system, the instructor holds another "intervention" in order to make sure that the students understand that forces are massless before the activity comes to an end. This case, as well as test and quiz questions throughout the quarter, are used to determine the effectiveness of the activities.

Figure 3. Massless Force Case

Since January of 2013, the team has been continually modifying this activity in order to achieve the maximum level of understanding in students (Self, et. al, 2015). Some examples of refinement include reorganizing the case order, adding additional cases to cement concepts, and switching the unit system to see if there is better conceptual understanding in either SI or U.S. customary units. This paper analyzes the hypotheses from the students for four different configurations of the activity in an effort to answer the following three questions:

- Which order of the cases leads to the most successful hypotheses in the later cases?
- Does the number of cases have an impact on whether hypotheses are successful?
- Does the unit system used, U.S. Customary or SI, improve student understanding?

Implementation/Method

This study includes data from classes over the past six quarters. Many of the quarters differ in the system of units used, case order, and data gathering methods. Examples of each quarter's activities can be found in Appendix A. One of the major changes between the quarters is that the activities were performed using U.S. customary units for the first three quarters, but were then converted to SI units for the latter three in an effort to reduce student confusion. The first three quarters also only consisted of four cases, while a fifth case that varied the masses and the total forces at the same time was added for the most recent three quarters. The order of the cases, the units used, and the number of students that participated each quarter are shown in Table 1 below.

Table 1. Units, Sample Size and Case Order for each quarter. The green quarters are quarters which have confidence level data available

Units	Quarter	Samples	Case Order
U.S. Customary	Spring 2014	63	= Force, varied Mass
			= Force, varied Mass
			varied Force, = Mass
			Massless force
	Fall 2014	67	= Force, varied Mass
			= Force, varied Mass
			varied Force, = Mass
			Massless force
	Winter 2015	70	= Force, varied Mass
			varied Force, = Mass
			= Force, varied Mass
			Massless force
SI	Spring 2015	145	= Force, varied Mass
			Varied Force, = Mass
			= Force, varied Mass
			Varied Force, Varied Mass
			Massless Force
	Fall 2015	49	= Force, varied Mass
			Varied Force, = Mass
			= Force, varied Mass
			Varied Force, Varied Mass
			Massless Force
	Winter 2016	70	= Force, varied Mass
			Varied Force, = Mass
			= Force, varied Mass
			Varied Force, Varied Mass
			Massless Force

Another difference between the quarters using U.S. customary units and those using SI units was the data collection method. The quarters using U.S. customary units were all given papers with the different possible outcomes and were told to write a check next to the outcome they believed would occur. This resulted in some illegible entries, especially if the student populated multiple outcomes or their final response was unknown. The team could not be sure if the student had a hypothesis and simply changed their mind on their own, or if they changed their answer sometime after either the team discussion or intervention. This led to some data being rejected if the answer could not be determined. In an effort to alleviate these problems, as well as avoid the time-consuming manual entry of the data, the hypotheses were converted into an online quiz hosted on the school's learning management system (Moodle). The quiz did not affect the students' grades so the students would not be afraid to guess and be incorrect in their hypotheses. The students access the online quiz via smart phones, computers, or tablets. The quiz is also designed so that there is only one case available to the students at a time, which prevents them from skipping ahead and making hypotheses before they observed the real system, which could have been a problem with the hypotheses submitted on paper. The online quiz was used to gather data for Spring 2015 and Fall 2015; however, for the activity of Winter 2016, the internet was not available and the students had to write their hypotheses by hand. Another modification between the many quarters was whether or not a confidence level was included for each of the hypotheses. Spring 2014 was the only quarter using the U.S. customary units that had a confidence level for their responses, while all of the quarters for the SI units have confidence level data available. The particular words used for the confidence levels varied slightly between quarters; the exact wording used can be viewed in Table 2.

Table 2. Confidence level choices for each quarter

Spring 2014	**Fall 2015/ Spring 2015**	**Winter 2016**
High	Very High	Very High
Moderate-High	High	High
Moderate	Moderate	Moderate
Low-Moderate	Low	Low
Low	Very Low	Very Low
Total Guess	Total Guess	-

One more adjustment was the transfer question case which was affected by the change from U.S. customary units to SI units. While the U.S. customary unit case showed a constant force of 10 oz, because all of the values were given as weight, the SI unit case was slightly more complicated in order to show a force equivalent to the weight of a 300 gram mass. In order to help the students understand that the constant force and weight force were identical, the force was written as (300grams)*g where "g" is gravity. After receiving some feedback from the students, it appears that seeing the "300 grams" confused some students and made them believe that the force somehow has mass. The effect of this will be discussed later in this paper.

Results

Figure 4 shows the percent of students who answered each case correctly for all six quarters, with quarters using U.S. customary units shown in blue, and those using SI units shown in red. It should be noted that some quarters had different case sequences. For instance, Case #2 of Spring 2014 demonstrated an equal force, varied mass system, while Spring 2015 Case #2 demonstrated an equal mass, varied force system comparison. The case orders can be seen in Table 3.

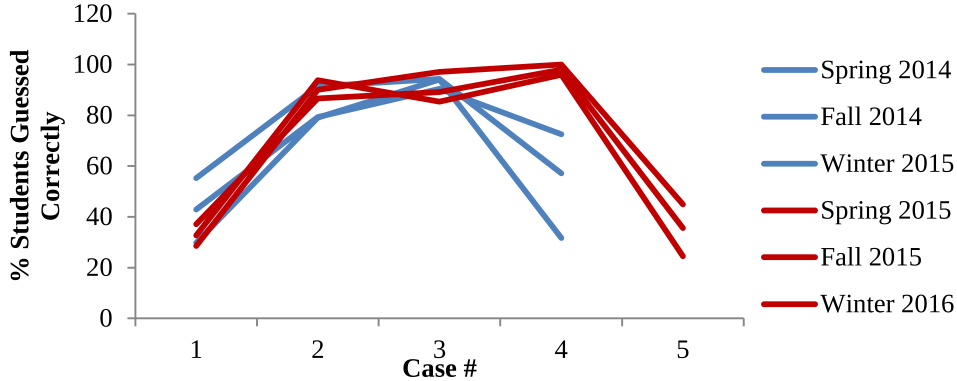


Figure 4. The trend of students hypothesizing the outcome correctly over time. The trends in blue represent the quarters that used U.S. customary units; the trends in red used SI units.

Initially, the percentage starts out low as would be expected. The quarters using U.S. customary units are either at or above the percentage of correct students for the SI units, with the average of the quarters using U.S. customary units being about 10% higher than the SI quarters as shown in Table 4. The SI unit worksheet provides students with the masses of each weight, while the U.S. customary unit worksheet states their weights directly. The first case for all the quarters is the same and demonstrates the effect that a different amount of mass, with the same total force, has on the acceleration. It is interesting that the quarters with U.S. customary units that were provided the actual forces, which are not the variable of interest in this case, had a higher rate of understanding prior to running the experiment.

Table 3. Case orders and percentages of students correct for each case for each quarter

	Case Order				
	1	**2**	**3**	**4**	**5**
Spring 2014	**Same F**	**Same F**	**Same M**	**Massless Force**	-
	42.86	79.37	90.48	72.58	-
Fall 2014	**Same F**	**Same F**	**Same M**	**Massless Force**	-
	29.85	79.1	94.03	31.75	-
Winter 2015	**Same F**	**Same M**	**Same F**	**Massless Force**	-
	55.22	91.43	94.29	57.19	-
Spring 2015	**Same F**	**Same M**	**Same F**	**Varied F & M**	**Massless Force**
	37.09	86.71	89.19	97.96	35.62
Fall 2015	**Same F**	**Same M**	**Same F**	**Varied F & M**	**Massless Force**
	32.65	93.88	85.42	95.92	24.49
Winter 2016	**Same F**	**Same M**	**Same F**	**Varied F & M**	**Massless Force**
	28.57	90	97.14	100	44.93

Table 4 studies the difference in accurate responses for each type of case depending on the units that were used that quarter. It should be noted that the order of the cases varied for each quarter and is not reflective of the way they are listed here.

Table 4. The average percentages of students for each case type who hypothesized correctly separated by the units used in the cases.

Unit Type	Same F (1)	Same F (2)	Same M	Diff F & M	Massless Force
U.S. Customary Units % Correct	42.64	84.25	91.98	N/A	53.84
SI Units % Correct	32.77	93.40	88.20	97.96	35.01

Figures 5 through 9 show the confidence results for each quarter by each case. The higher confidences are displayed in green, while the less desirable confidences are shown in orange and red. Spring 2014 was the only quarter which used U.S. customary units and had confidence data available; this quarter's results are displayed with a gradient to differentiate it from the other quarters. Spring 2014 also only had 4 cases, while the other quarters had an extra case which varied the total force on the system and the total mass at the same time. The quarters had the cases in different orders so these graphics show the progression of the students' confidence over the course of the activity rather than a direct comparison between the cases.

Figure 5. Percentages of the various levels of confidence for each quarter for Case 1

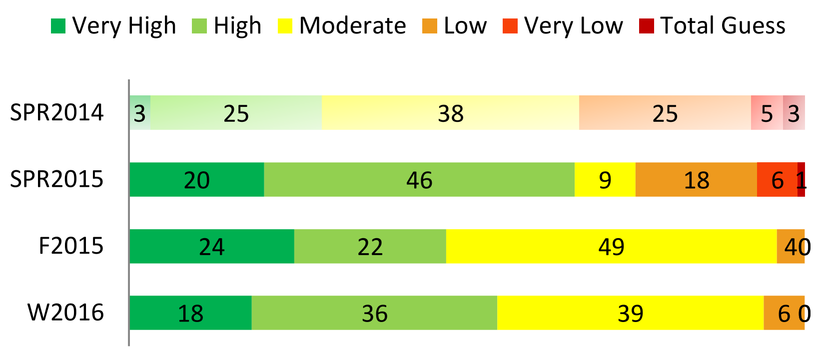


Figure 6. Percentages of the various levels of confidence for each quarter for Case 2

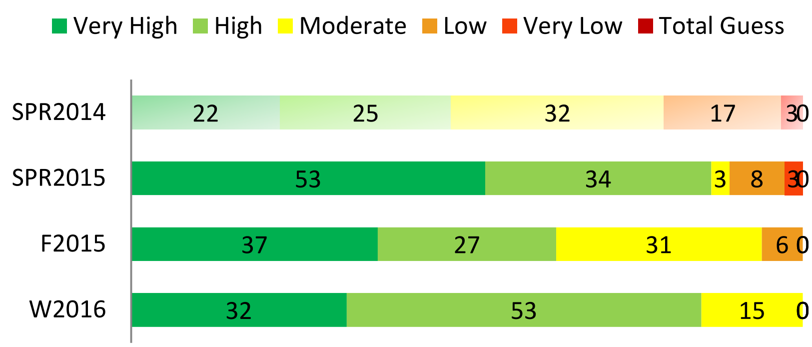


Figure 7. Percentages of the various levels of confidence for each quarter for Case 3

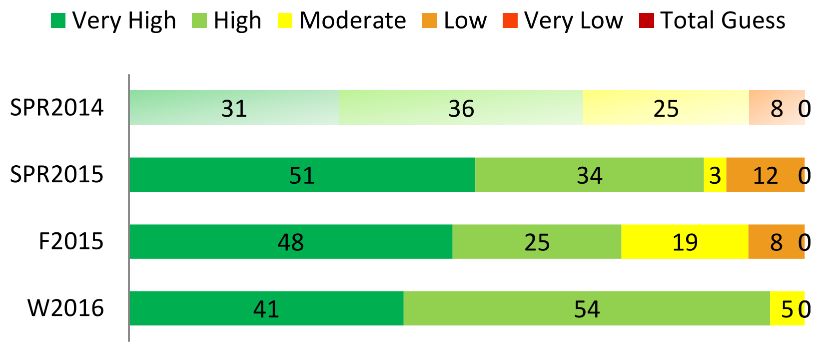


Figure 8. Percentages of the various levels of confidence for each quarter for Case 4, the case which varied force and mass at the same time. The activity for Spring 2014 did not include this case and only had four cases total.

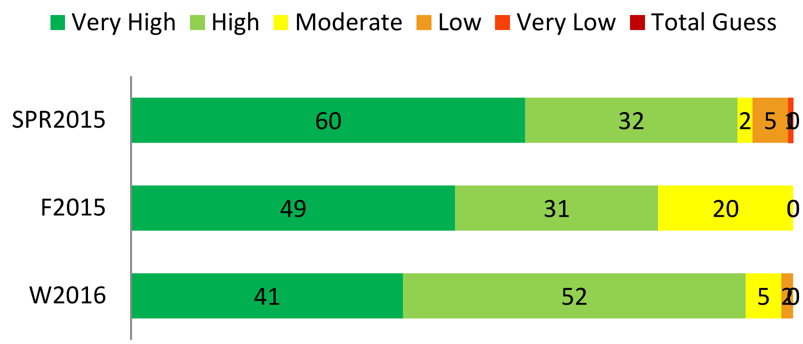
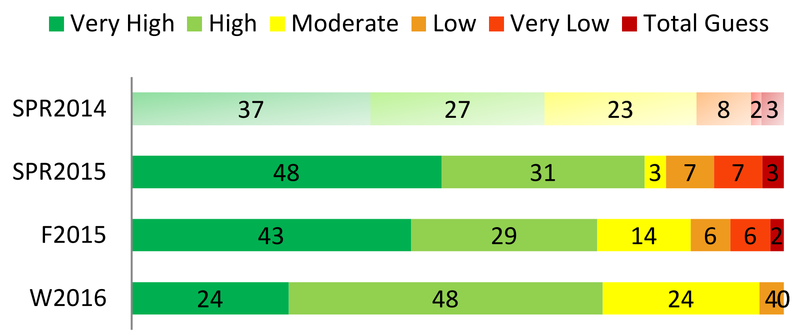


Figure 9. Percentages of the various levels of confidence for each quarter for the transfer question. For Spring 2014, the transfer question was the fourth and final case; for the other quarters, the transfer question was the fifth and final case.



Discussion

The trend of the percentage of students who predicted correctly over the course of the activity is shown in Figure 4. In most classes, students typically use the SI unit system so it was hypothesized that using that system on the cases would increase their understanding, and avoid the confusion associated with proper U.S. customary conversions using slugs since understanding units is not the primary goal of these activities. However, based on Case 1 which was identical for all quarters other than the unit change and best represents the students' understanding before any intervention, it appears that the students were actually more successful in U.S. customary units.

For the second case, the activities in the Spring and Fall quarters in 2014 again compared systems of varied masses and equal total force, while the other quarters took a new approach and observed a comparison of equal mass and varied net force. It would be expected that the quarters with a nearly identical comparison would perform better, since the purpose of the intervention was to explain the proper way to analyze those systems for that type of comparison. However, the average of those two quarters is actually around 79% of students who successfully hypothesized the expected outcome, while the quarters with a new variable being adjusted had an average of around 89%, or 10% more successful. Interestingly enough, the highest scoring quarter for the second case performed was Winter 2015, which performed the same mass, varied net force (a different approach than the first case they performed) and used U.S. customary units.

The general trend for the remainder of the cases excluding the transfer question is an improvement in the students' understanding and ability to predict the outcome. The quarters with SI units performed an additional case that varied both the total force on the system and the total mass of the system, which can be viewed in Figure 10. In this case, the winning system has both a greater total force and a lighter mass. This case is a combination of both desired concepts, that force is directly proportional to acceleration and mass is indirectly proportional to acceleration. However, in this particular case both of the variables increased the acceleration, so a student could have arrived at the correct answer using only one of the desired concepts, so it is uncertain whether they truly understood both of the concepts based solely on this case. As would be expected, the students performed extremely well on this case, with around 97% students getting it correct.

Figure 10. SI Case with both total force and total mass varied

All of the quarters showed a dramatic decrease in percentage of students correct when faced with the transfer question, however the classes using SI units scored remarkably poorer at around 35% of students correct, compared to the U.S. customary units at around 54%. As discussed previously, this poor performance can likely be attributed to the obscure description of the force being applied to the system and does not properly represent whether the students understood the material. For a better measurement, the case will have to be reworded to explicitly state that a force equivalent to the weight is applied and remove any suggestion of mass on that side of the pulley. The case with the U.S. customary units used a measure of the force in ounces, which is less confusing than the wording of the SI unit case, and therefore can be used to gauge the level of understanding. There was a large drop from the students' understanding of the previous two cases which is undesirable, but scores did improve from the initial case by about 10%, which shows that some learning did occur over the course of the activity. It should be noted that after the students make their hypotheses and discuss with their peers, the instructor holds an intervention to inform students that the force is massless, and therefore that system will have a faster acceleration. The data analyzed in this paper is solely the hypotheses of the students so any learning that took place after the hypothesis is not shown. The students take the Dynamics Concept Inventory (DCI) at the beginning and end of each quarter which, along with testing results, would serve as a better representation of whether the students understood the concept of the massless force. These results have been reported by Widmann (2014).

The available confidence levels were analyzed and the confidences for each case were graphed. These trends are visible in Figures 5-9. Not including the transfer question, the percentage of students who stated they had the highest level of confidence increased over time. This can be seen by the desirable confidences "Very High" category shown in green increasing in each case, excluding the transfer question. The increase in understanding is obviously a desired trend, and is expected to correlate with student understanding. The "Moderate", "Low" and "Very Low" trends decreased through the cases, suggesting a shift to higher confidence. Interestingly, the trend for the "High" confidence level remained mostly steady throughout the activity for all of the quarters. One theory that could account for this is that students who enter a problem with very little background have little confidence, but once they begin to understand a problem, they feel a dramatic increase in confidence. In comparison, students who come in with prior knowledge and have an understanding of the system and would already start with an "High" confidence level do not feel any significant increase in confidence and therefore remain at a consistent level throughout the entire activity and would not feel as motivated to adjust their confidence to "Very High".

Spring 2014 was the only quarter with confidence level data available that used U.S. customary units. This quarter followed the other quarter's trend pretty similarly, but it did have many more students choosing the "Moderate" confidence level, rather than the "Very High" or "High" levels. Spring 2014 also had a higher number of students that ended with below "Moderate" confidence than any of the other quarters. This might be attributed to the change in units, because the students are more familiar with SI units and feel they can manipulate the numbers and units more easily than the units dealing with slugs in the U.S. customary system.

All of the quarters using SI units had a decline in the number of students who chose the highest confidence level for the transfer question case, which is somewhat expected since the transfer question exposes them to something new and removes them from their comfort zone. As was already discussed, the wording of that case was confusing to some students and this fact could have also lowered their confidences, merely because they didn't understand the problem statement. The likelihood of the wording being at fault is supported by the results for Spring 2014, in which the number of students who chose the highest confidence level actually rose for the transfer question. More data must be taken with a better worded question before a conclusion can be reached.

Conclusion/ Future Research

The research questions that this paper set out to answer are repeated below:

- Which order of the cases leads to the most successful hypotheses in the later cases?
- Does the number of cases have an impact on whether hypotheses are successful?
- Does the unit system used, U.S. Customary or SI, improve student understanding?

Overall, not many firm conclusions can be drawn from the data thus far without more research. With so many improvements and changes made over the course of these six quarters, it makes it difficult to prove causation because of any one particular change so these questions cannot be answered separately as is desired. In order to reach any significant conclusion in the future, only one adjustment must be made at a time in order to determine the effect that each component adds. However, the overall performance and confidence of the students did improve in the last three quarters which shows that the changes that were made did have a positive impact. As shown by the increase in percentage of students correct in Case 2 and Case 3, it is likely that students are more successful when the order of the first three cases is "Same Force", "Same Mass", "Same Force". Giving them a different changing variable as the second case forces the students to immediately question both the forces and the masses effect on the system, whereas giving them two "Same Force" questions could allow them to cement an idea early on that it is only the force which matters, which could be detrimental to later cases. However, this increase in correct answers could also be attributed to the switch in unit system; further research is needed.

The students performed better overall with five cases and had a higher confidence after the fourth case than earlier quarters with only four cases. As shown in Table 4, the highest percentage of correct students occurred for the "Varied Force, Varied Mass" case of the quarters which used SI units. It is not clear what factors contributed to this success: the switch to SI units, the simplicity of the case itself, or the students having more practice analyzing the system. More research must be done to pinpoint whether the students truly understood the question. Rather than changing both variables that result in the same effect of increasing the acceleration, the students should be presented with a case that requires calculations to determine the outcome. For example, the total force should be increased, which should increase acceleration, and the mass should also be increased, which should decrease acceleration. The students would have to effectively use Newton's 2nd Law to determine the correct mass that would accelerate, which would be a good indicator for whether the students fully understand the relationships involved. While the initial indication still suggests that having five cases was more successful for students, again more research must be done and a more challenging question will be more helpful to gauge whether the amount of practice is truly improving student understanding.

Whether the switch from U.S. Customary units to S.I. units improved student understanding seems likely but would still require more research to be positive. All of the cases, excluding Case 5, had higher confidence levels when S.I. units were used. Also, the overall performance was improved. However, as was stated previously, these statistics could also be due to the change in case order. In the future, it is also clear from the analysis that the massless force transfer question needs to be improved in order to increase student understanding. The low number of correct hypotheses combined with the low confidence shows that the phrasing of the SI units confused the students and did not fulfill its role as a transfer question. Possibly a better way to describe the constant force would be to state that gravity is equal to a value (such as 10 m/s^2) and state the force in Newtons. Because these activities are focused on hands-on learning, it would be interesting to see how much understanding would increase if the students were able to actually see this massless force case in action. Some attempts have been made to design such a system, but the complicated variables involved have prevented it from coming to fruition. Instead, a computer simulation is being generated that could potentially show the students what would occur, which brings up an additional research question of the different effect that simulations can have on student learning compared to hands-on activities.

There are many more adjustments that took place that could be studied in depth. For example, in this day of technology, it would be useful to know the effect of working on worksheets and quizzes on a device rather than on paper. Does the device provide a level of disconnect from the activity by taking their attention away from the hardware as the user needs to think instead about navigating the web pages? Or does the device make the answering portion more effortless so that the students can focus more on understanding and discussing with their teams? These questions and many more have evolved from the Mass Pulley IBLA, and more research will be performed to continue improving and helping students understand the difficult concepts of dynamics.

Acknowledgments

Funding for this research was secured through the National Science Foundation from the grant: Using Inquiry-Based Activities to Repair Student Misconceptions in Engineering Dynamics (NSF 1044282).

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*Georgette, J., Self, B.P., Widmann, J., *Bohn, K., and Wang, E. (2013) Rolling, rolling, rolling: An inquiry-based learning activity in dynamics. Proceedings of the 2013 American Society for Engineering Education Pacific Southwest Annual Conference, Riverside, CA.

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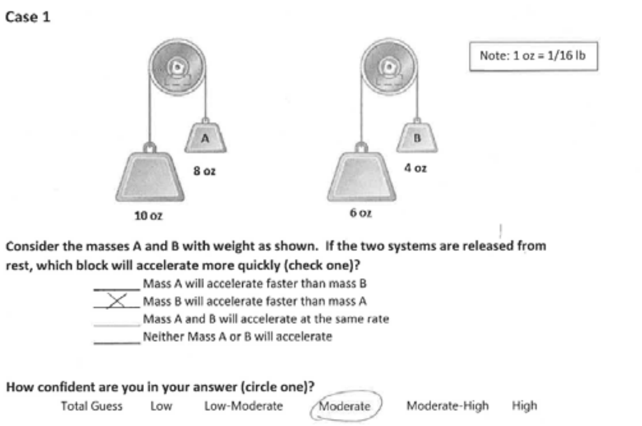
*Student author

Appendix A: Student Handouts for Each Quarter

SPRING 2014


Case 1

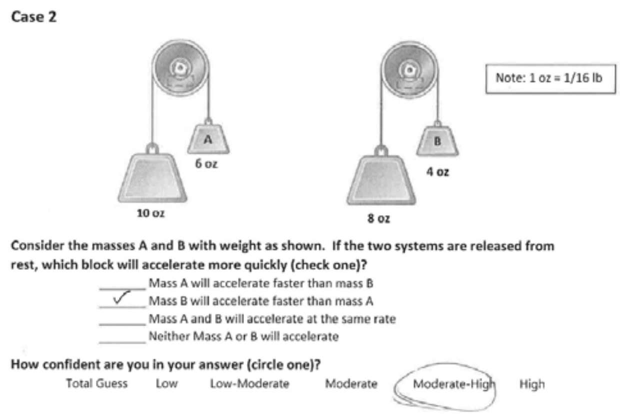
Note: 1 oz = 1/16 lb

A 8 oz; 10 oz; B 4 oz; 6 oz

Consider the masses A and B with weight as shown. If the two systems are released from rest, which block will accelerate more quickly (check one)?

___ Mass A will accelerate faster than mass B
_X_ Mass B will accelerate faster than mass A
___ Mass A and B will accelerate at the same rate
___ Neither Mass A or B will accelerate

How confident are you in your answer (circle one)?
Total Guess Low Low-Moderate (Moderate) Moderate-High High


Case 2

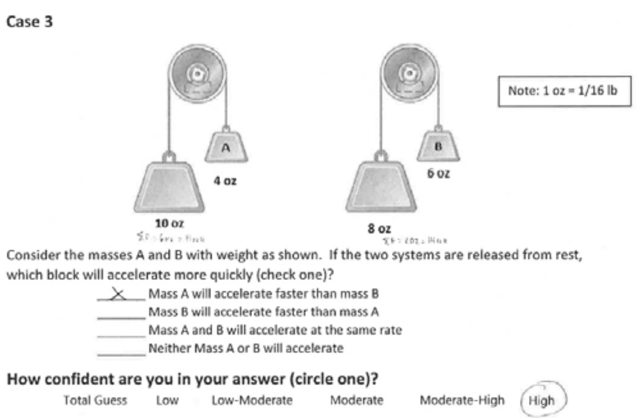
Note: 1 oz = 1/16 lb

A 6 oz; 10 oz; B 4 oz; 8 oz

Consider the masses A and B with weight as shown. If the two systems are released from rest, which block will accelerate more quickly (check one)?

___ Mass A will accelerate faster than mass B
_✓_ Mass B will accelerate faster than mass A
___ Mass A and B will accelerate at the same rate
___ Neither Mass A or B will accelerate

How confident are you in your answer (circle one)?
Total Guess Low Low-Moderate Moderate (Moderate-High) High


Case 3

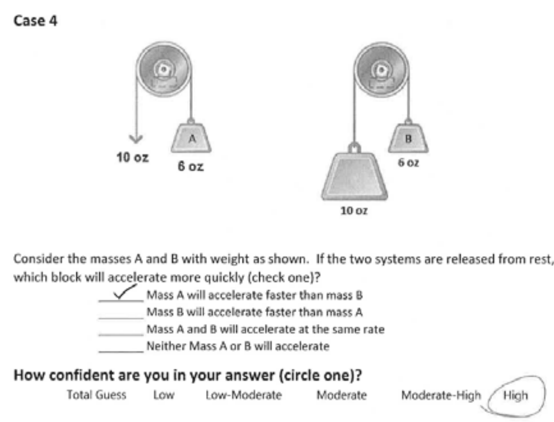
Note: 1 oz = 1/16 lb

A 4 oz; 10 oz; B 6 oz; 8 oz

Consider the masses A and B with weight as shown. If the two systems are released from rest, which block will accelerate more quickly (check one)?

_X_ Mass A will accelerate faster than mass B
___ Mass B will accelerate faster than mass A
___ Mass A and B will accelerate at the same rate
___ Neither Mass A or B will accelerate

How confident are you in your answer (circle one)?
Total Guess Low Low-Moderate Moderate Moderate-High (High)


Case 4

10 oz; A 6 oz; B 6 oz; 10 oz

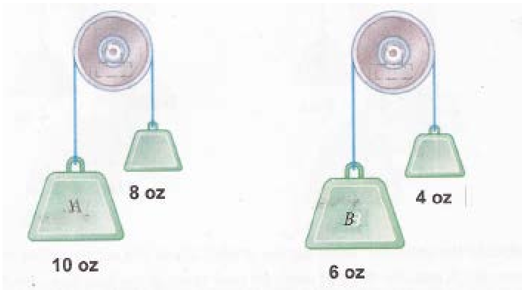
Consider the masses A and B with weight as shown. If the two systems are released from rest, which block will accelerate more quickly (check one)?

_✓_ Mass A will accelerate faster than mass B
___ Mass B will accelerate faster than mass A
___ Mass A and B will accelerate at the same rate
___ Neither Mass A or B will accelerate

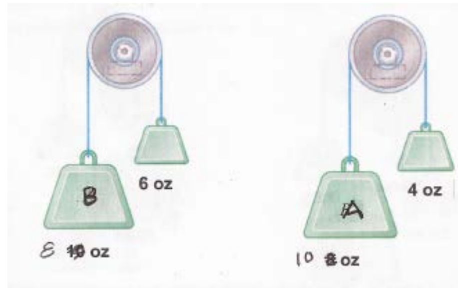
How confident are you in your answer (circle one)?
Total Guess Low Low-Moderate Moderate Moderate-High (High)

FALL 2014 Cases

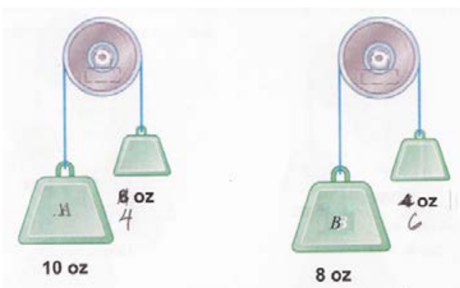
Case 1



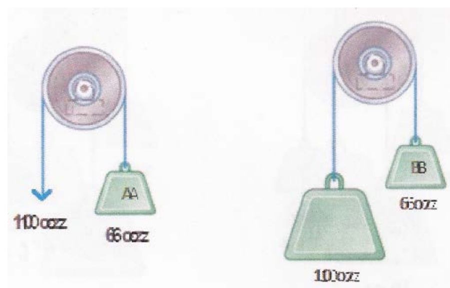
Case 2



Case 3

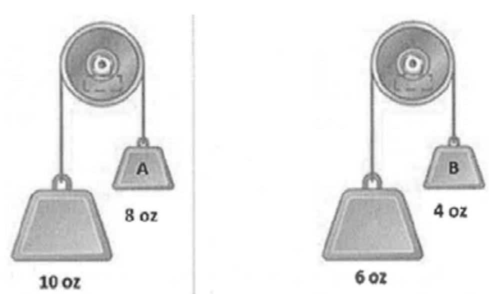


Case 4

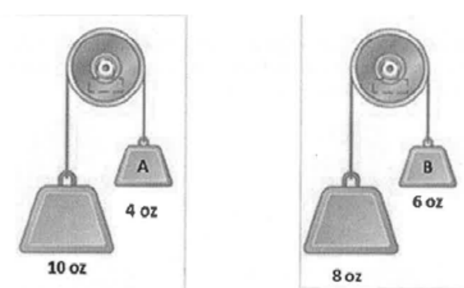


WINTER 2015 Cases

Case 1

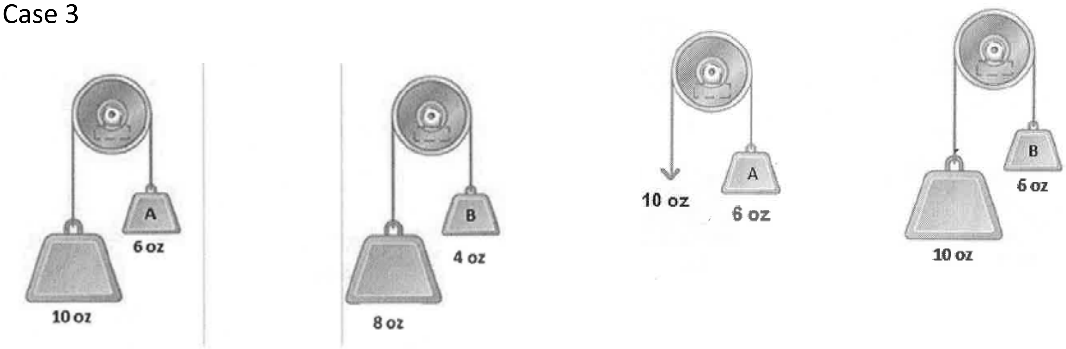


Case 2



Case 4

Case 3



Individual Prediction Sheets Used in Fall 2014 and Winter 2015

Mass-Pulley IBLA Individual Prediction Sheets

Case 1:

As an individual (before discussing as a team), what do you predict about the accelerations of the masses if they are released from rest? Indicate your predication below.

______ Mass A will accelerate downwards faster than mass B
______ Mass B will accelerate downwards faster than mass A
__✓__ Mass A and B will accelerate downwards at the same rate
______ Neither Mass A or B will accelerate downwards

Case 2:

As an individual (before discussing as a team), what do you predict about the accelerations of the masses if they are released from rest? Indicate your predication below.

______ Mass A will accelerate downwards faster than mass B
__✓__ Mass B will accelerate downwards faster than mass A
______ Mass A and B will accelerate downwards at the same rate
______ Neither Mass A or B will accelerate downwards

Case 3:

As an individual (before discussing as a team), what do you predict about the accelerations of the masses if they are released from rest? Indicate your predication below.

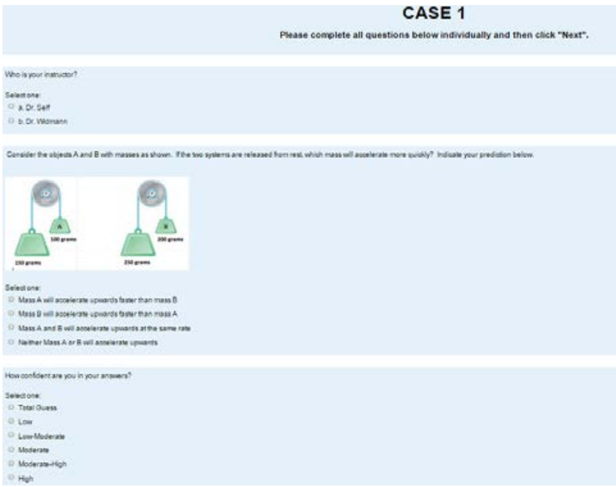
__✓__ Mass A will accelerate downwards faster than mass B
______ Mass B will accelerate downwards faster than mass A
______ Mass A and B will accelerate downwards at the same rate
______ Neither Mass A or B will accelerate downwards

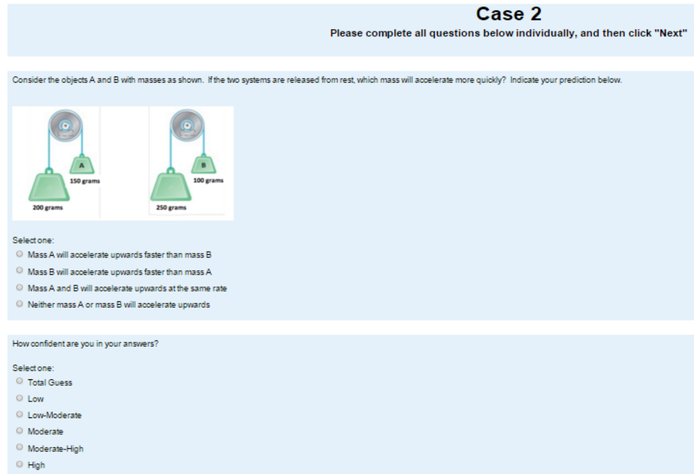
Case 4:

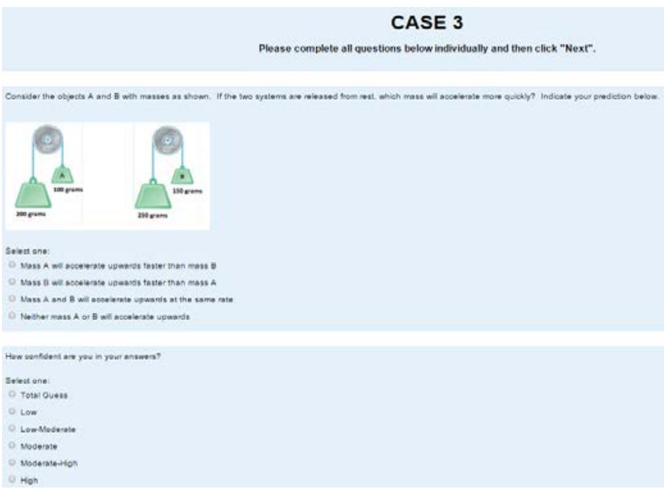
As an individual (before discussing as a team), what do you predict about the accelerations of the masses if they are released from rest? Indicate your predication below.

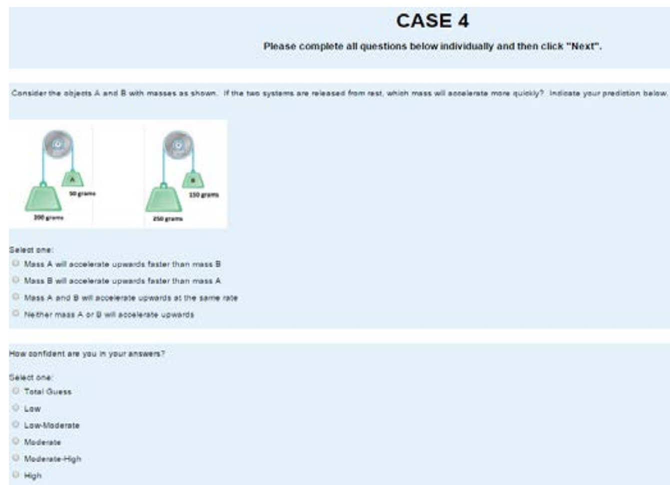
__✓__ Mass A will accelerate upwards faster than mass B
______ Mass B will accelerate upwards faster than mass A
______ Mass A and B will accelerate upwards at the same rate
______ Neither Mass A or B will accelerate

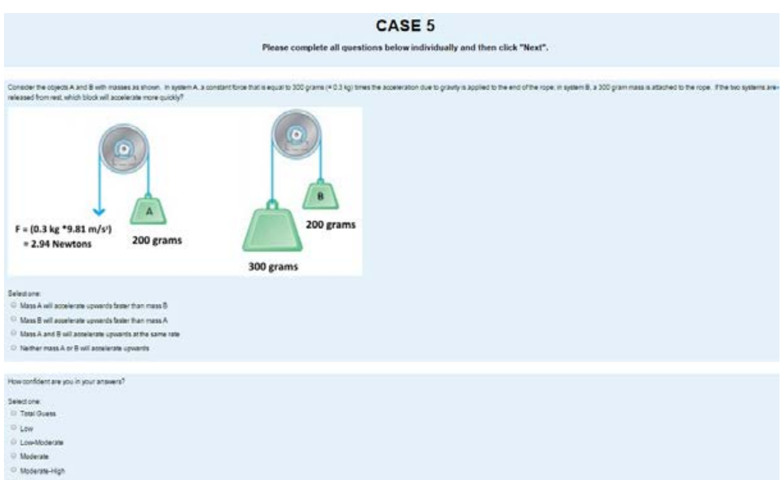
SPRING 2015, FALL 2015, and WINTER 2016 Individual Predictions Quiz











Engaging Community College Students in Structural Engineering Research through Natural Period Approximation for Steel Plate Shear Wall Structures

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Abstract
Building design specifications are developed in order to provide safety, reliability, and efficiency of building designs. For seismic building codes, the design base acceleration is calculated using estimated natural period of the structure by ASCE 7-10 (American Society of Civil engineering). This paper presents a summer intern project that engages community college students into structural engineering studies through comparing empirical values with periods obtained through finite element analysis. Community colleges serve as the gateway to higher education in the United States. Engaging community college student is of significant interests for the San Francisco Bay Area and the state of California. With support from the US Department of Education through the Hispanic-Serving Institution Science, Technology, Engineering, and Mathematics (HSI STEM) program, four community college engineering students participated in a ten-week summer research internship program at San Francisco State University in 2015. Mathcad and OpenSees are used to design and analyze structures varying in height, bay width, and shear resistance. This research internship program allows for the development of project management, time management and teamwork skills, thus helping strengthen students' knowledge of seismic design and prepare them for successful academic and professional careers. The internship program therefore provides valuable mentorship for community college students during their transition to a four-year college and their decision to pursue a civil engineering profession.

Introduction
Earthquake engineering is concerned with design and analysis of structures to withstand earthquakes at specific locations. Civil engineers need to find ways to build more efficient and cost-effective buildings that have the capability to resist various natural hazards such as earthquakes and high winds. Steel Plate Shear Walls (SPSW) structures have been investigated since the early 1970's in the United States, Canada and Japan. Generally, a SPSW consists of a vertical steel infill plate connected to surrounding beams and columns as shown in Figure 1. The beams and columns are often referred to as horizontal boundary elements (HBEs) and vertical boundary elements (VBEs), respectively. The steel web-plates are installed in one or more bays along the full height of the structure to form a cantilever wall. Boundary elements are designed to allow the web plates to develop significant diagonal tension. An example of this system is the Hyatt Regency Hotel in Dallas. While advances in research on the behavior of SPSWs continue, some aspects of its behavior still remain unclear. Estimating the fundamental period of a SPSW is one of these areas where more research is required. The fundamental period of a structure is

used in initial design for the calculation of seismic load. Current code and provision has been shown to produce overly conservative approximations for an SPSW system when compared to that from more accurate finite element analysis. This overly conservative approximation could lead to costly designs and unnecessary iterative design.

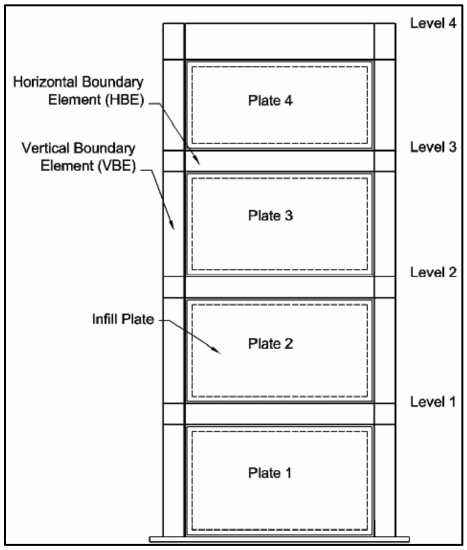

Figure 1. Typical SPSW configuration

Community colleges such as Cañada College serve as the gateway to higher education for large numbers of students especially in California. However, for science and engineering fields, lower success and retention rates are observed at both community college and university levels resulting in underrepresentation of minority groups in these fields. The NASA CiPair program between SFSU and Cañada College addresses some of these barriers to the successful transfer of community college engineering students to a four-year institution including inadequate preparation for college-level courses, especially in mathematics, low success rates in foundational math courses, lack of practical context in the traditional engineering curriculum, and inadequate relevant internship opportunities for lower-division engineering students.

Cañada College is a member of the California Community College System, and is one of three colleges in the San Mateo County Community College District. It is one of only two federally-designated Hispanic Serving Institutions in the San Francisco Bay Area. During the 2011-2012 academic year, the College enrolled 10,965 unique students. The student body is genuinely multi-cultural with Hispanic students as the largest single group at 35.5%; white students comprise 32.6%, Asians 8.1%, Filipinos 3.4%, African-Americans 3.9%, Pacific Islanders 1.7%, American Indian/Alaska Natives 0.3%, multi-racial 9.5%, unknown 4.9%. The objectives of the NASA CiPair project are: (1) to improve student engagement and success in foundational math courses and core engineering courses; (2) to provide ten participants each summer with research experiences in NASA Ames, which they would not otherwise have in their usual academic environment; (3) to provide current community college students a year-long engineering design experience early in their academic career by participating in capstone design courses for graduating seniors; (4) to strengthen existing faculty relationship with NASA Ames, and establish new collaborative relationships among two-year and four-year engineering faculty, and NASA Ames Research Center; (5) to increase the number of academically prepared community college students transferring to four-year institutions as engineering majors; (6) to improve academic success of engineering students from underrepresented groups by providing academic support and mentoring; and (7) to increase the number of minority students pursuing advanced degrees in STEM fields.

Summer Intern Project Description

In summer 2015, a total of twelve students were selected through an application process and participated in the CiPair Program. Four of these twelve students chose to work on a civil engineering project of designing and analyzing SPSW structures at San Francisco State University. The project was split into three main parts; design of the structures, modeling the structures and analyzing the data from OpenSees (McKenna *et al.* 2010). The SPSW prototypes in this study are modeled after structures described in the SAC joint venture (Gupta and Krawinkler 1999) using a Los Angeles structure with a seismic design category D with the floor plan shown in Figure 2. The SPSW structures are designed in accordance to the procedures outlined in AISC Design Guide 20 (Sabelli and Bruneau 2000), and requirements from AISC 341-10 (2010). The design base shear was calculated using the equivalent lateral force procedure from ASCE 7-10 (ASCE 2010). Building weights were calculated using 86 psf for roof dead loading and 96 psf for dead loading on a typical floor. From ASCE 7-10 the response modification factor, R, overstrength factor, Ω_0, and deflection amplification factor, C_d are given as 7, 2.5, and 6.5 respectively.

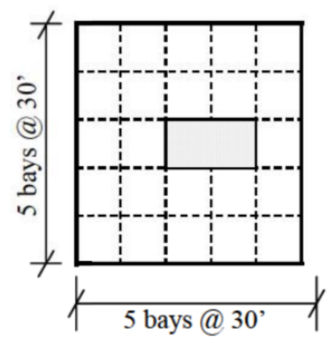

Figure 2. Floor plan for SPSW prototypes

The four intern students are expected to create a total of twenty-seven structures varying in height, bay width and shear resistance in web plate. Structures varied from 5, 8 and 10 stories high with different bay widths of W (20 ft), M (15 ft) and N (10 ft). Base shear resistance of 100%, 85% and 65% were used for the design of steel web plates. All structures had the parameters of soil classification D (stiff soil profile) and were in accordance to the specifications outlined in the AISC Design Guide 20. The 27 structures were then modeled using OpenSees to calculate the structure's natural periods. The data collected from OpenSees analysis will then be compared to the natural periods obtained from the current code ASCE 7-10.

Summer Intern Project Outcome

Tables 1 to 3 present the final design of 5 story SPSW structure with 20 ft bay width for 100%, 85% and 65% design base shear, respectively. Similarly, a design process was performed for all the rest 24 SPSW structures.

Table 1 Final Design of 5W SPSW for 100% Base Shear

Floor	**HBE**	**VBE**	**Steel Plate Thickness (in)**
Roof	W21X122	-	-
5	W21X132	W14X145	0.0418
4	W16X77	W14X211	0.0897
3	W18X97	W14X193	0.1198
2	W21X211	W14X257	0.1345
1	W33X263	W14X311	0.1495

Table 2 Final Design of 5W SPSW for 85% Base Shear

Floor	**HBE**	**VBE**	**Steel Plate Thickness (in)**
Roof	W21X211	-	-
5	W14X159	W14X132	0.0359
4	W14X193	W14X176	0.0673
3	W16X77	W14X211	0.0897
2	W16X77	W14X193	0.1048
1	W27X217	W14X370	0.1198

Table 3 - Final Design of 5W SPSW for 65% Base Shear

Floor	**HBE**	**VBE**	**Steel Plate Thickness (in)**
Roof	W18X97	-	-
5	W18X86	W14X132	0.0269
4	W16X77	W14X132	0.0538
3	W16X77	W14X145	0.0673
2	W14X48	W14X176	0.0897
1	W30X211	W14X176	0.0897

As the main objective for this internship, the natural period calculated using the ASCE 7-10 equation is being compared with the natural period obtained using OpenSees. The following Tables 4 to 6 present a comparison of the natural periods obtained with both methods.

Table 4 Natural periods for 20ft bay width SPSW structures

Natural Period W Structure						
Base Shear (%)	**5 Story**		**8 Story**		**10 Story**	
	ASCE 7-10	OpenSees	ASCE 7-10	OpenSees	ASCE 7-10	OpenSees
100	0.46	0.63	0.65	0.89	0.77	1.19
85	0.46	0.69	0.65	1.02	0.77	1.31
65	0.457841	0.816603	0.651336	1.084881	0.769994	1.490479

Table 5 Natural periods for 15ft bay width SPSW structures

Natural Period M Structure						
Base Shear %	**5 Story**		**8 Story**		**10 Story**	
	ASCE 7-10	OpenSees	ASCE 7-10	OpenSees	ASCE 7-10	OpenSees
100	0.457841	0.714749	0.651336	1.122846	0.769994	1.350059
85	0.457841	0.760162	0.651336	1.225236	0.769994	1.444340
65	0.457841	0.872477	0.651336	1.390814	0.769994	1.641355

Table 6 Natural periods for 10ft bay width SPSW structures

Natural Period N Structure						
Base Shear %	**5 Story**		**8 Story**		**10 Story**	
	ASCE 7-10	OpenSees	ASCE 7-10	OpenSees	ASCE 7-10	OpenSees
100	0.457841	0.810764	0.651336	1.496496	0.769994	1.561730
85	0.457841	0.844721	0.651336	1.553760	0.769994	1.687312
65	0.457841	0.937201	0.651336	1.574820	0.769994	1.900735

Figures 3 to 5 present the graphic comparison of the natural periods for all SPSW structures. It can be observed that the code estimations are different from those from OpenSees.

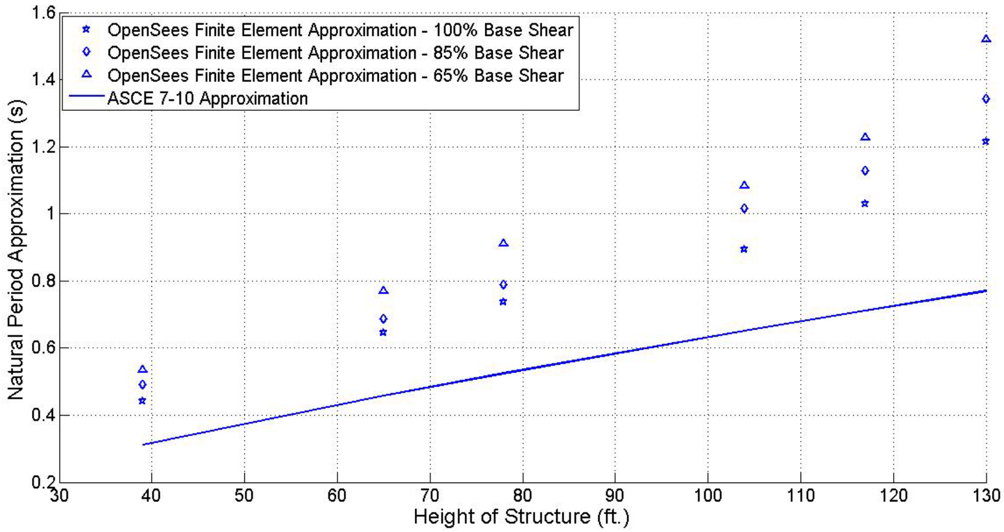

Figure 3 Comparison of natural periods for 20ft bay width SPSW Structure

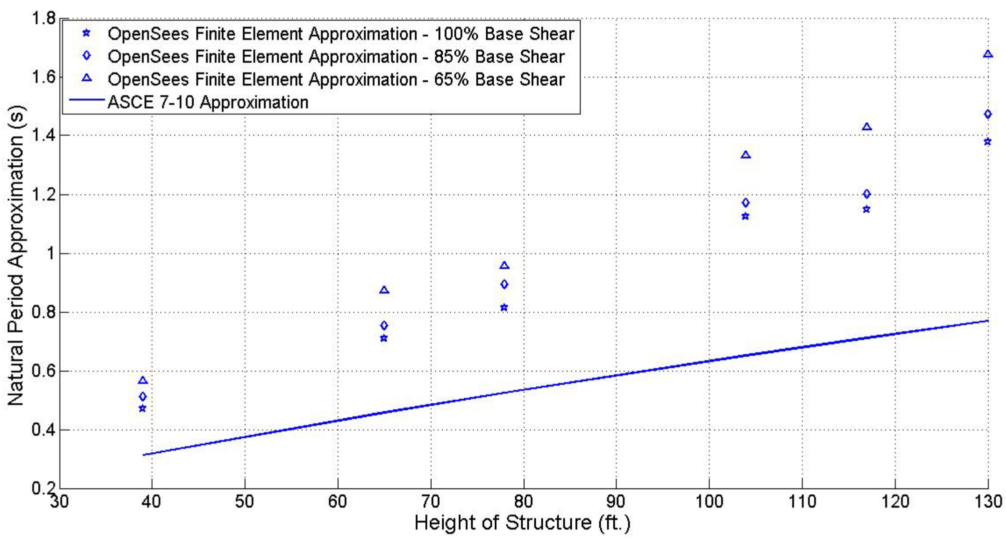

Figure 4 Comparison of natural periods for 15ft bay width SPSW Structure

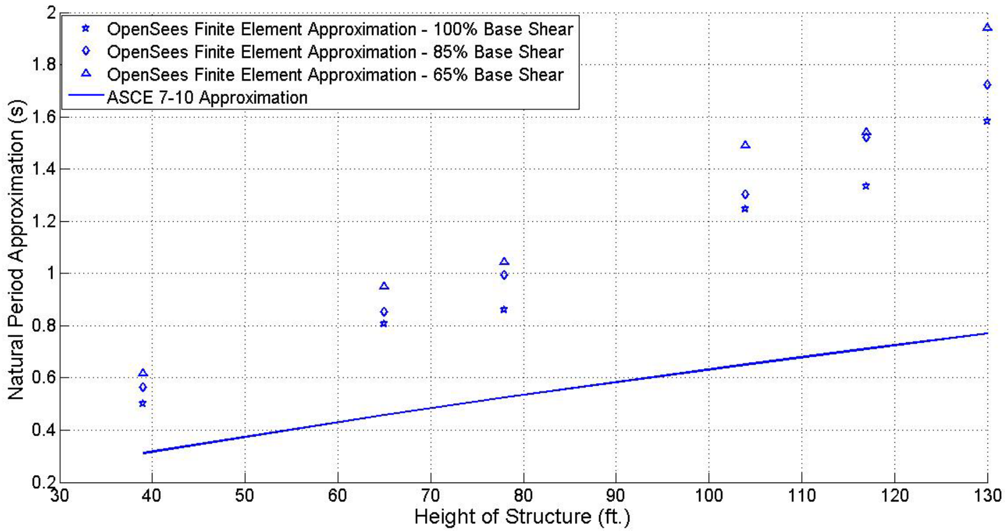

Figure 5 Comparison of natural periods for 10ft bay width SPSW Structures

Figures 6 to 8 present the comparison of natural periods for all different stories of SPSW structures.

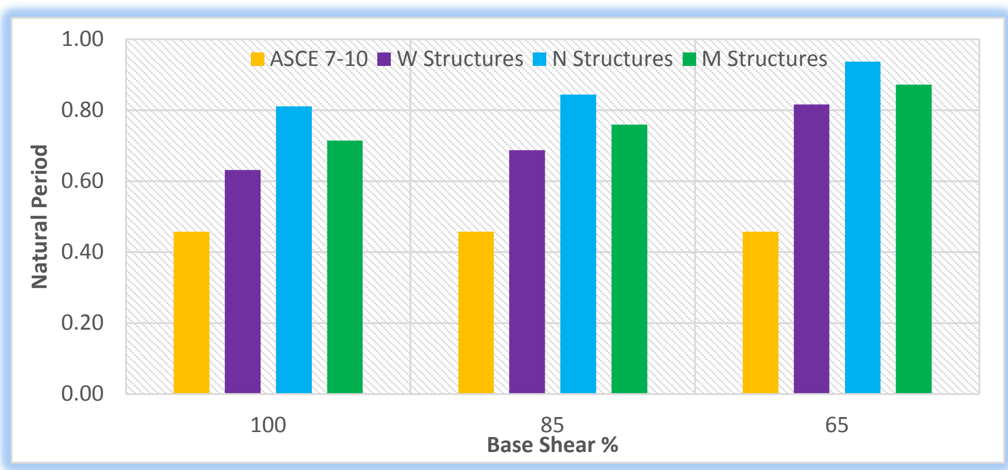

Figure 6 Period comparisons for all 5 Story SPSW structures

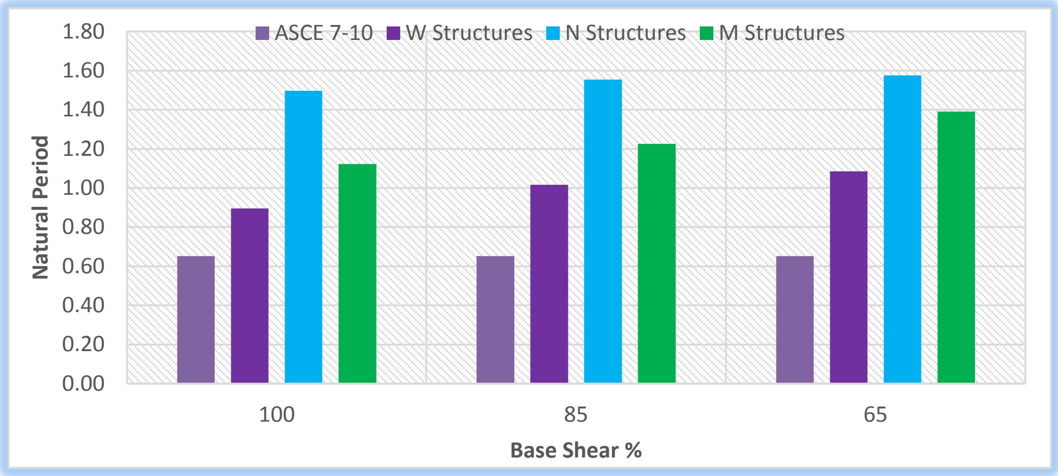

Figure 7 Period comparisons for all 8 Story SPSW structures

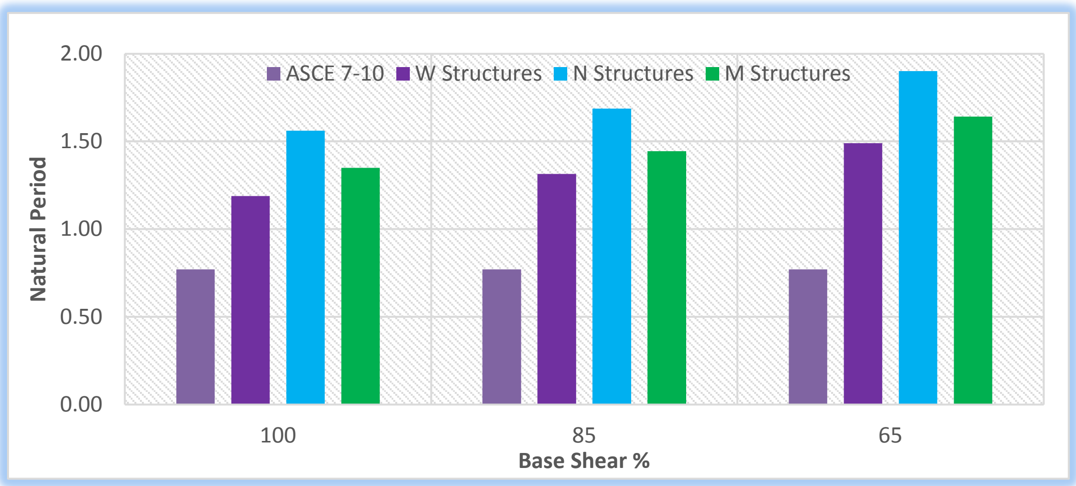

Figure 8 Period comparisons for all 10 story structures

In addition, the interns also conducted an error analysis, as shown in Table 7, for all SPSW structures when compared with code estimated natural periods. An average error around 45% is observed, implying again that the code provides over conservative estimation.

Table 7 Error analysis for the natural periods of all SPSW structures

W Structures (20ft Bay Width)			M Structures (15ft Bay Width)			N Structures (10ft Bay Width)		
NO. Stories	Base Shear %	% Error	NO. Stories	Base Shear %	% Error	NO. Stories	Base Shear %	% Error
5	100	27.50	5	100	35.94	5	100	43.53
	85	33.41		85	39.77		85	45.80
	65	43.93		65	47.52		65	51.15
8	100	27.20	8	100	41.99	8	100	56.48
	85	35.95		85	46.84		85	58.08
	65	39.96		65	53.17		65	58.64
10	100	35.24	10	100	42.97	10	100	50.70
	85	41.41		85	46.69		85	54.37
	65	48.34		65	53.09		65	59.49

Project Assessment and Future Improvement

The internship experience enabled the interns to realize how trained civil engineers in the field will have to collaborate with other members on their team. Trained civil engineers will need to make weekly meetings with their supervisor to discuss their progress on their design and provide feedback on what they can improve. They will need to make a detailed, tentative plan that they must follow until their deadline when the building must be constructed. The research project could not have been completed by one engineer because it takes teamwork and collaboration on everyone's part to get the project done.

To obtain a quantitative assessment of the project and further improve the project in the future, an exit survey was conducted for all twelve student participants. Students were asked to rate their level of agreement with each question in a five point scale: 1 – Not at all useful; 2 – A little; 3 – Some; 4 – Quite a bit; 5 – A lot. The tables below present the students' response to some of the survey questions. The survey was conducted anonymously to help student express their opinions honestly.

Question: As a result of your participation in the program, how much did you learn about each of the following?

Activity	Average Rating
Performing research	4.81
Designing/performing an experiment	4.75
Creating a work plan	4.63
Working as a part of a team	4.63
Writing a technical report	4.75
Creating a poster presentation	4.69
Making an oral presentation	4.81

Question: Tell us how much you agree with each of the following statements.

Activity	Average Rating
The internship program was useful.	4.69
I believe that I have the academic background and skills needed for the project.	4.38
The program has helped me prepare for transfer.	4.31
The program has helped me solidify my choice of major.	4.13
The program has helped me solidify my choice of transfer university.	4.06
As a result of the program, I am more likely to consider graduate school.	4.13
As a result of the program, I am more likely to apply for other internships.	4.75
As a result of the program, I am more likely to consider SFSU as my transfer institutions, or recommend it to others.	3.19
I am satisfied with the NASA CIPAIR Internship Program.	4.50
I would recommend this internship program to a friend.	4.63

When asked the question "what do you like most about the NASA CIPAIR Internship Program?' Typical response from the civil engineering group students are: “I like the fact that we work in a group on a research project. We gain the experience and knowledge of working as a group.” “The problem that we were given was a graduate level problem for student civil engineers. This project helps us advance our skills in civil engineering.” “I liked how each day I had the chance of learning something new about my major and the principles that goes with Electrical Engineering.

Summary and Conclusion

The NASA CiPair program has been very successful in helping students understand civil engineering topics and the engineering profession. Responses from the student participants are very positive. Among the students who solidified their choice of an engineering career and decided to major in one of the engineering fields, the program has provided context to their study of engineering – a strategy that has been proven to increase student motivation and persistence – especially as they struggle through the first two years of the engineering curriculum.

Acknowledgement

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Self-Directed Learning: Transitioning from College to the First Engineering Job

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Abstract
As an extension of a four-year, mixed-methods study of the development of self-directed learning (SDL) of a cohort of college students, we followed up with nine individuals after graduation to examine how they might or might not be exhibiting SDL attitudes and behaviors in their first jobs as engineering professionals. Through a questionnaire, we set out to examine how their identity, motivations, and ideals may have changed as they began to practice engineering in different roles and at different organizations. This paper discusses our research questions and data gathering efforts, and begins to organize the data with the findings from our previous studies. Employing social-cognitive theories of motivation and self-regulation (Deci and Ryan, 2000; Pintrich, 2004), we report on the cohort's levels of motivation (i.e., external vs. internal), autonomy, goal setting, help-seeking strategies, and self-assessment. In addition, we seek to understand their ability to initiate and pursue their own goals within the context of their current work environment and culture. We examine how they now define "success" and what their future aspirations are. This study of our new graduates in the very early stages of their career provides insight into how particular undergraduate engineering experiences might affect self-directed learning skills and attitudes that contribute to life-long learning after graduation.

Background

This study began as a National Science Foundation (NSF) Transforming Undergraduate Education in Science, Technology, Engineering, and Mathematics (TUES) grant to investigate the development and deployment of self-directed learning (SDL) of engineering students during the first two years of college. The study originally tracked a cohort of 30 freshmen in the Materials Engineering (MATE) department at Cal Poly, SLO. As time passed, students dropped out of the study and new transfer students entered the study cohort.

In the course of this longitudinal study, we discovered that validated, quantitative survey data on students' SDL skills and attitudes did not significantly change over time (Stolk, 2014). Qualitative responses to open-ended prompts from online, written surveys and focus groups, however, revealed rich, nuanced descriptions of how students' ongoing transformations as self-directed learners (Chen, 2015). For instance, students gained a better understanding and appreciation for self-directed learning after experiencing open-ended projects in courses that gave them the freedom to discover and fail, while also having the "appropriate" amount of guidance. In addition, students who had summer internships seemed to demonstrate more comfort with self-directed learning. Thus, this paper concentrates on only qualitative data about the transition from college to the first engineering job, and it fits within a larger context of the development of self-directed learning of college students.

As we shifted the study focus from quantitative surveys to qualitative focus groups, we narrowed the cohort of thirty to approximately a dozen students who were most engaged in participating in the study. All the students experienced the MATE curriculum together, and thus had similar learning experiences. They were exposed to different teaching pedagogies that varied from highly structured, content-heavy courses to more open-ended, self-directed project courses. The cohort in the study graduated in June 2015. Approximately 6 months after graduation, we examined the extent to which study participants were exhibiting SDL behaviors in a non-school setting. Our research questions are informed by social-cognitive theories of motivation and self-regulation and are as follows:

1) What does motivation for self-directed learning (SDL) look like after transitioning from college to the workplace? What are study participants' goals now, and what does "success" mean to them?
2) What are SDL indicators for new engineering professionals, and are these related to the SDL indicators in school settings? Do professional SDL indicators relate to SDL in undergraduate experiences?
3) How do the SDL attitudes and behaviors reported by college students persist when they graduate and transition to early career stage engineers? Does the degree of SDL that they displayed as students affect their career choices?

Study Participants and Data Collection

In January 2016, we sent an email request to follow up with nine individuals who had attended more than one focus group prior to graduation. This group included seven men and two women, a gender ratio reflective of the student demographics in the undergraduate program. We purposely designed the study with limited participants in order to dive deeper into their responses and to inform future research directions. Attached to the email were an informed consent form and a questionnaire with five prompts for information and reflection (Appendix 1). Similar to the study by Alderton (1999), we intended to collect evidence from new engineers to understand what is being learned, how, and the influences. All nine responded within three weeks. Individuals were offered a gift card for completion of the questionnaire as an incentive.

Work Environment

In contrast to the pre-graduation data collection, in which meaning was developed collectively in focus groups, students responded individually to the post-graduation survey. In addition, whereas individuals experienced the same undergraduate engineering program, their post-graduation professional experiences could vary widely. Out of the nine alumni, two were still seeking jobs, and the remaining seven had been working three to six months. The seven graduates who were employed worked in different companies and had different job titles (Table 1). One alumnus had recently changed jobs. From the reported job descriptions, some jobs appeared to have more opportunities for self-directed learning than others (e.g., research and product development vs. manufacturing), but all had aspects of problem solving. Individuals reported working both individually and on teams, and all reported to a manager or supervisor(s). While some of the engineers relied on what they learned from the MATE curriculum content, some responded that they wished they could use more of what they learned in their current job. Almost all of them noted that there was still much to learn. We noted particular themes to our research questions and provide quotes from the responses to our questionnaire in the following three sections.

Table 1. Job title and industry of the study participants in the cohort

Engineer #	Job Title, industry
1	R&D engineer, biomedical industry
2	Corrosion engineer, energy/oil industry
3	Quality engineer, manufacturing
4	Seeking biomedical position
5	Production Associate, steel and ship building company
6	Product development engineer, solar company
7	Staff scientist at National Lab, research
8	Seeking employment
9	Process Engineer, biomedical industry

Findings

Motivation, Goals, and "Success"

Because motivation is inherently tied to self-directed learning (Pintrich, 2004), the cohort in this study has been asked various times about their motivation to learn in school and elsewhere. This study sought to identify what motivates new working engineers (or what they imagine it to be, if they were not working yet). External motivators typically present in undergraduate engineering programs, such as good grades or experiences to put on a resume to get a job, are no longer relevant at this point. We find that individuals express different motivators, and most of them are internal. In addition, the goals as a college student of obtaining their degree and a job are no longer common, and now career goals begin to differentiate.

Two engineers identify freedom to take initiative or creativity as their motivation.
Motivation means taking the initiative. People at the lab are encouraged to do patents for inventions they create at the lab. For me, I am always looking for how to solve problems that arise in projects with creative solutions. I can't talk about the specifics of everything I do, but I will sometimes, try a small experiment to verify a theory before seeking approval for a bigger experiment. These motivated moments arise when i think I have a good idea and just REALLY want to know if i am right. That is enough to get me to take the initiative. [Engineer #7]

I am particularly motivated when I am given an "empty canvas" for problem solving. I love solving real-world problems. It is something I am very passionate about. I love throwing crazy ideas at the wall and seeing what sticks. Sometimes only part of the idea stays, but something can often grow from what's left. And you're left with something new that resembled the old, but performs much better! Engineering new things is the best feeling. Knowing that you took an idea from your head, designed it in a computer, printed it with a 3D-printer, and then testing it and seeing it actually work is an amazing feeling. [Engineer #6]

Another engineer talks about making progress or getting work done as motivation.
Motivation at work is the condition of my work ethic that enables me to operate at peak productivity. It is somewhat pushed by intrinsic motives (ie will power, maybe 40%), but mostly pushed by somewhat extrinsic motivators (ie pressure to perform, mental stimulation of the task at hand, maybe 60%). … I am often particularly motivated when I am tasked with an intellectually challenging job that I can feel I am making progress on as I work on it. If it is too boring, the task feels menial, unimportant, and not worth my time. If I cant tell whether or not I am making a progress on a task, it is easy to get discouraged and feel defeated, so some kind of measurable progress is key. When motivated, time seems to fly by and a sense of pride comes with completion of the job. [Engineer #5]

These differences in motivations and goals leave us with questions about what and how we provide the appropriate motivations and curricula activities for college students for life-long learning.

Another engineer is motivated to be part of the whole and to feel that they are contributing, while another talks about getting motivation from being with others, and demonstrate "relatedness" identified as one of the three psychological needs in self-determination theory (Deci and Ryan, 2000).
In general, motivation at work comes from a feeling that I am an integral piece of a process in which the members of the working team are interdependent. … It is very easy for me to see the context of the work I am doing as it pertains to company functions overall… That ability to help the process along gives me a good feeling of value to the larger process, and in turn motivation to perform well. The more menial tasks like labeling and cutting metal don't provide as much motivation because I don't feel as needed in that role. [Engineer #3]

I often feel unmotivated when I don't have people around to fuel me. I have discovered that in professional environments that people fuel my energy and motivation. With[out] interaction with colleagues I feel useless and unneeded, which is an interesting feeling. I think it is most important to have interaction so that you feel needed as an employee. [Engineer #1]

One individual still seeking a job summed up the components that others had mentioned (i.e., creativity, productivity, working with others) all at once:

I hope that it [the job] *is structured with freedom to allow my future coworkers and I to be productive and stay on task as well as be happy to know that we have the freedom to be creative and innovative.* [Engineer #4]

As students, our cohort had a clear goal of getting their degree and they all did achieve that goal. But now, we inquired into what their goals were now. In their early stage of their career, did they see a future in their current company or did they have their sights on something else already (e.g. a different path or graduate school)? Were they identifying intermediate steps to achieve those long-term goals? And was there any connection to how they define success?
For one individual, their goal is very specific, and attainable – something that the person can identify with.
Related to work, I think success would be being in a position where I was considered a subject matter expert. I certainly think that with time this is a very attainable goal. I would love one day to be the person that other corrosion engineers within the company turn to for help with an issue or project. … One of my mentors at the refinery is widely respected because of his knowledge and ability to implement it in a way that produces continuous safe operation for the refinery. I would love to one day be able to fill that role. [Engineer #2]

It is interesting to note this person didn't start out with this goal as a student, and actually had strong interests in a very different area of materials. However, the individual reported in an earlier focus group that during the interview, they felt a pleasant sense of expertise (or mastery) with their knowledge, or "competence" in self-determination theory (Deci and Ryan, 2000). Thus becoming an expert and feeling needed in the company provided great motivation.

None of the study participants said that success meant having lots of money or prestige. Some talked about success in the context of their role with their job, and we discuss "job fit" later. A couple of responses described "success" as a process rather than an end goal; meaning it was never anything to actually attain but something to work towards, whatever it might be.
I think success to me means achieving the things I want in way that makes the struggle worth it. I am always looking forward to the next thing, so success is never something I am going to "reach," more of something that occurs as I keep going. [Engineer #6]
I also don't believe that any of these should ever be considered "achieved". Rather, there should be levels of achievement to reflect upon and feel proud of, but "being successful" should be a living process of continuous improvement in any or all of the areas defined by the individual. I think that attainment of 'meta-success' can have a multiplicative effect on the sense of fulfillment one feels from their personal successes. [Engineer #3]

Through the course of this study, participants have practiced reflection for several years now, both through written course assignments and in focus group discussions. We have noticed their display of a high level of maturity over time.

Self-Directed Learning Indicators on the Job and Connections from College

Throughout this multi-year study, we have examined how students relate to open-ended projects, autonomy, choice in the classroom, as well as SDL behaviors such as help seeking and goal setting. In the context of their first engineering jobs, do the study participants recognize when they are exhibiting self-directed learning as working engineers on the job or on their own time? Do they relate any of their SDL activities to experiences as students in college?

The study participants did identify SDL activities that they have taken upon themselves and not due to anyone in particular assigning them to do so. Sometimes it was in context of being able to do their job well, such as learning engineering codes to ensure quality and safety, or to be well versed and confident with ASM and ASTM Standards used in their jobs. Others might be learning to augment their current job (such as learning LABVIEW) or to seek better opportunities. One individual relays that in order to get ahead, they should get an advanced degree and learn a programing language.

I shortly discovered that life is a constant learning process. In these short 7 months of working, I have decided that I want to pursue a higher education in Materials Science. ... If you lay dormant in current job position you will get left behind and left uninvolved in a lot. … I have ventured out on my own to learn how to program. I've noticed that engineering is trending highly digital, even in materials science. Computational Materials Science is a huge evolving field that I would love to see me career evolve into. With this desire comes the desire for me to learn python. So many evolving technologies are using this language, which is not really taught in schools. [Engineer #1]

The new engineer describes the beginning of the self-regulated learning cycle, as described by Zimmerman (2000) of having predefined set of cognitions and self beliefs (such as goal setting and self-efficacy), and the example is outside of any external entity assigning the goal.

Many talked about learning from others on the job, and there was an attitude of doing whatever it took to figure things out or do whatever was needed with a "growth mindset."

I rely heavily on my more experienced co-workers, but now that I have learned where a lot of the technical resources are stored, I spend a ton of time reading and attempting to figure things out on my own first. My usual routine now is to take a stab at the problem, and then cc my mentor on emails so that he can review what it is I have worked on. [Engineer #2]

I will learn what I have to in order to get the job done. … There will be hundreds of more self-directed learning opportunities for me over the next 40+ years. I know that I am capable of learning anything. It just comes down to resources and my determination. [Engineer #6]

Many mentioned that school was where they learned "how to learn." Through their SDL activities in college, they gained practice in diving into a specific area of knowledge and in figuring out the approach that suited them. Educators in higher education realize that we should strive to provide foundations for our students in which a lifetime of learning in work and elsewhere can be built.

… reminds me of the way I'd go about taking in knowledge in some of the MATE labs. There would often times be some framework for inquiry provided by the instructor, but … the content and scope of the lab was completely up to the team. That freedom to investigate and become specialized in some small field of knowledge bears a lot of similarity to the way I've gone about learning the standards I mentioned. [Engineer #3]

While my work here is more directed than some of the self-directed projects we did in school I still feel that I have freedom in the way I learn what I need to. … The learning you do must come from working with others or figuring things out yourself. In this way, the self-directed projects are very helpful in preparing you for the way you need to learn in industry. [Engineer #9]

Understanding where to go for technical resources is a huge advantage in this job. There is a fine balance between taking a stab at something yourself first and going to another person for advice. This is a bit like the relationship between students and professors at Cal Poly. Most of the Cal Poly staff would be willing to answer questions for you if you could show that you had looked through the textbooks and familiarized yourself with the material first. Similarly, the upper management and technical experts within my company can answer questions, but they do not have all the time in the world to explain a concept from the very beginning. [Engineer #2]

It was also interesting to see that what could inhibit SDL on the job was similar to what students encounter in school when the feel defeated about a course or concept.
I have been unmotivated several times in this job role. Those times came within the first few months of this job and were attributed to not understanding a task and not knowing who to reach out to for help. Knowing that you have a project to do, but not knowing how to do the project is a huge de-motivator. [Engineer #2]

Several of the responses recognize the need to be agile and to learn on the job, and report how their college education prepared them with the mindset and practice to figure out how to do things on their own. The use of resources (e.g., handbooks, standards, consultation with experts) in college continued into their professional work. Most of the study participants described an occasion where they set their own expectation or goal beyond the immediate job requirement, and then took steps to achieve those goals. The reported SDL behaviors connected to school experiences suggest that intentionality in curricula design for SDL can result in desired outcomes for our graduates. Furthermore, Boud and Falchikov (2006) argue that curricula and assessment should be designed for learning for the long-term, and not just immediate learning requirements.

Degree of Self-Directed Learning and Finding Fit with a Job
Due to the length of this study on the development of SDL, we've been able to observe changes in individuals, as well as growth among the cohort over the years. We also gauged level or degree of self-directed learning of the participants, although we are also cognizant of our own biases that may play into the interpretations. We have gotten to know these participants over 4+ years, and have also developed a research relationship with them. We have also questioned how

SDL attitudes and behaviors might be part of one's personality, and how much our learning environments and curriculum can affect changes. Did the students who showed larger degree of SDL continue to do so, and did the students who preferred more instructor-directed activities go on to seek out or relate to their jobs in similar ways?

With self-assessment an important component in SDL, the degree of reflection varied among the cohort and along a continuum. We were also mindful of ensuring a range of people for the study. Reflections are a deliberate part of several MATE courses, and very important in this study with the focus groups and open-ended survey questions. We noted that some spoke of experiences across time – connecting the past to the present, and/or the present to the future. King and Kitchener (1994) notes that someone who is highly reflective sees themselves in the context of others and within a larger world.

We observed that one individual's responses to the most recent set of questions were strikingly self-focused. The words "I" and "me" dominated the responses and the person didn't really mention others at all in any way. This individual was probably the most consistent in their responses throughout the study, and there was a quality of fixed attitudes and abilities with this person. As a student, this individual was driven to perform well and was practical about learning.
My performance at work is heavily fueled by the same self directed learning that I experienced at Cal Poly. Self directed learning is at the root of my ability to stay self motivated, propelling me to complete tasks to the best of my ability, even when no one is watching. This increases the overall value and performance of me as an employee. [Engineer #5]

In contrast, another individual would consistently relate themselves in context of others (even as a student), and not unsurprising, seeks that relatedness with others in a job.
I think I most enjoy serving others in the medical industry because it brings health and happiness to others through engineering. I think I would love to work in a team of engineers who seek health and happiness for others and encourage one another daily. [Engineer #4]
This person not only sees the purpose of the job to serve others but also sees working with others as an important component to the job. We earlier saw an individual (Engineer #2) wishing to become an expert in order to help others.

We also see reflective capacity as an important component in determining whether there is the right "fit" with a job and company for a person.
When I first got out of college, I worked for a terrible company. One that did not care about employee safety, continuous improvement, or making better products. It was terrible. I would spend days doing absolutely nothing. Getting paid to stare at my computer screen or walk around the building. Asking my employer for work and getting no answer. It was mundane, life sucking, and awful. But I learned some extremely valuable things. I learned what is important to me in a job. And I learned where I stand in regard to ethical practices. I left that job after only 5 months of "work." And it was a great decision, because I love the company I am at right now. [Engineer #6]

Another individual is currently contemplating a change in career plans, after realizing that initial expectations were not met. Interestingly, this individual showed the most growth during our study during college. This person had an epiphany in the 3rd year of college that grades had no relationship to what was learned or the effort put into the learning.
The biggest lesson that I have learned in working is that getting your first job is not the end all. I was so preoccupied with getting a job so that I didn't have to worry about anything…. I have found myself contemplating taking a $10,000 pay cut just to do something I find more valuable and interesting. [Engineer #1]

We also note an effort to make meaning to one's job in order to align their values and ideals, as well as their identity as an engineer, with their current position.
I am motivated by achieving the best results possible. I know that the devices I am working on will eventually be used to either save lives or increase the quality of life for someone. This motivates me to make the best part possible. In addition making a process more efficient or robust is also particularly motivating. The feeling you get when you finally get a better yield or a dimension within spec is amazing. [Engineer #9]

This individual was very involved with an international service club in engineering as a student and consistently talked about doing things for a greater purpose than the self. While individual's personality traits begin to emerge over time, the focus of the study is SDL. The students who persisted in the research tended to be social and formed bonds in the process of focus group meetings. As Holland's (1985) theory suggests, two or three personality traits tend to align with environmental aspects of satisfying potential careers. To test his theory, he and his colleagues developed a number of self-directed search assessments that match personality types with aspects of particular careers. In retrospect, these assessments might have proved useful to our study in an earlier phase of the research. Nevertheless the early career survey finds some congruence between student SDL and early career behaviors. Overall, we do see patterns in our participants in regards to the degree of self-directed learning displayed in college and continuing into their jobs. We hope to continue our analysis and to place it within context of our larger study and other learning theories.

Conclusions

With only 3-6 months into their first (or second) full-time engineering job, we captured a snapshot of how a cohort of engineering graduates was navigating the beginning stages of their careers, and how their college instruction may have had an influence. We observed some striking differences in how they viewed school work as opposed to work on the job – namely that work was no longer "optional" and that they took responsibility performing at high levels. They all seemed engaged in their jobs and had developed a sense of where they fit within their organization. We also noted that the stakes are quite different now. The preoccupation and pressure of grades or finding a job (for some) are now gone. As new engineers, there was an acceptance that they were not perfect and had lots to learn. Most of them described situations in which they were directing their own learning based on their own self-imposed directive.

They also seemed to have a different disposition towards "failure." As students, we witnessed a great fear of failing in certain classroom contexts, while in other classes, a liberating feeling of learning with the acceptance or even encouragement of "failing." Thus this dichotomy of environments may have helped them understand the conditions for their own success and may have influenced the type of job they selected. One individual commented on the value of the experiencing a range of classroom structure, norms, and expectations, as well as the diversity of approach to teaching/learning among the instructors within the department.
Looking back at my experience I think that the combination of structured lecture courses with self-directed projects was just great. I know that there is a lot of perceived and real conflict between the two but I hope that other students and the faculty recognize the value of having both in the curriculum. They can work so well together and I hope that the MATE department can continue to embrace both. [Engineer #9]

The responses from all the new engineers fit Zimmerman's model of self-regulated learning: goal setting and self-beliefs, engaging in and monitoring their performance, and self-reflecting. Self-regulated learners have the ability and skill to independently and proactively engage in self-motivating and behavioral practices to attain their goals. The study participants were able to identify influences from their college experiences.

An important outcome of this study is to better understand how to design educational experiences that will encourage self-directed learning. We find that students are most motivated to learn in school when there is a connection to the "real world" and when they value the assignment. There was more engagement with authentic projects, especially when there are real clients (e.g., industry sponsored senior projects).

While it is encouraging that the new engineers' experiences in the early phase of their career align with patterns of motivation and behaviors in their undergraduate program, it is useful to note their reporting of the need for more learning on the job. The breadth of their new positions indicates that "learning how to learn" is a key component of acquiring a positive disposition toward SDL. Whether working independently or in teams, these new engineers display a readiness to learn whatever it takes to be contributors to their professional assignment. The outcome of this smaller study underscores a shift in thinking about college students (and their degree program) from concluding at graduation but extending to the long term and lifelong learning.

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Appendix 1. Questionnaire emailed to study participants

1. Please tell us about your current job. Include the following:
   - company, location
   - job title
   - job description and responsibilities
   - who you report to
   - job environment (e.g., work alone or on team, structured/freedom)
   - what you do and how it is related to MATE
2. Broadly, what does motivation at work mean to you?
   - Can you recall a specific moment at work when you were particularly motivated? What do you attribute your motivation to at that particular moment?
   - Can you recall a specific moment at work when were particularly unmotivated? What do you attribute your motivation to at that particular moment?
3. Describe what you have learned on the job about the job.
4.
   a) Please describe any self-directed learning opportunities post-college (at work or otherwise) that you have encountered.
   b) In what ways can you connect your current engineering performance at work to the self-direction that you exercised as a MATE student at Cal Poly?
5. What does "success" mean to you? (i.e., How would you define it?)

A Multi-Institutional Study of the Relationships between Nontraditional and Traditional Undergraduate Engineering Students

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Abstract

Recent demographic trends in higher education show an increasing fraction of adult students over the age of 25. Adult students can benefit classroom culture and academic performance in college and university classrooms, and it is important to promote retention of this important demographic. Studies of adult students demonstrate the importance of social integration and positive adult-traditional student relationships to the retention of adult students. Few studies have examined these relationships in the context of engineering education, where challenging academic demands may impact the degree to which adult students engage socially with their traditional peers. This study examines semi-structured interviews collected from adult engineering students at three diverse institutes of higher education, including a small private university, a community college, and a large public research university. By applying perspectives from Kasworm's adult education work to characterize "otherness" and the types of relationships between adult and traditionally aged peers, we find that the adult engineering students in our study relate to two types of relationships: viewing themselves as different from less mature and less committed traditional age students, and having mutual respect and admiration for the academic engagement of their traditionally aged peers or friends. These two views are commonly held by the same student and at the same time, and may be especially salient during group work and the prioritization of time. We did not uncover explicit examples of a third negative type of relationship in which younger students view adult students as lessor and challenge their belonging in the environments. Finally, the majority of participants across institutions, especially those above the age of 30, listed their age and added life commitments as a major barrier in relating to traditional students and feeling socially included. Engineering educators and administrators can be aware of these types of relationships and make an effort to promote social integration and positive interactions between adult students and their younger peers.

Introduction

In recent years there has been a notable shift in the rate of increase in enrollment of students over the age of 25; NCES projects that the rate of increase of students over the age of 25 will outpace the rate of increase of traditionally aged students through 2023 (Snyder, & Dillow, 2015). This trend represents a shift in the average classroom demographic of all institution types, leading to a classroom made up of an increasing percentage of students over the age of 25. The increasing presence of adult students will likely have a desirable effect on the learning experience of all students. A study by Darkenwald and Novak (1997) revealed that in both community colleges and research universities adult student commitment to active learning was beneficial to the classroom culture. The study revealed a positive relationship between the overall class academic performance and the proportion of adults to traditional students. However, a report from the Multiple-Institution Database for Investigating Engineering Longitudinal Development revealed that this valuable demographic graduates at a lower rate than their traditional engineering peers. Understanding the educational experience is of key importance if educators hope to improve retention of adult students.

In order to seamlessly integrate adult students into classrooms, it is essential to recognize that this group of students face unique challenges that the majority of traditionally aged students do not. Institutions must redefine themselves to serve a student population that is not inherently assumed to be comprised of full-time, residential youth. Adult students are significantly more likely to be married, have dependents, commute, work full time, and have meaningful professional experience. These key differences can serve as sources of division between the groups, resulting in adult students identifying as "others" within the learning community due to their age. Adult students feeling socially alienated can have serious negative effects on their academic experience; it has been found that a critical factor for successful student integration is the development of friendships with peers (Swail, 2004). Tinto (1975) suggested that students who were successful in socially integrating into their campus community built commitment to their institution; this increased commitment results in a student with a higher likelihood of graduating. It is therefore pivotal to promote social integration of adult students, a task that can only be accomplished if the current barriers to doing so are well understood.

This multi-institutional study seeks to characterize the nature of the relationships between adult engineering students and their traditional counterparts with the intention of identifying areas in which adults do and do not feel socially integrated into their academic communities. Additionally, by investigating how and why adult engineering students see themselves as not fitting into the culture in challenging engineering programs, we may begin to identify strategies for engineering educators to actively promote inclusivity.

Background

Otherness

Institutions of higher education primarily aim to serve full-time, residential youth. Prioritization of this group is reflected in public policy, programming, mission, and the projected public image of the institution, resulting in the marginalization and neglect of adult student learners. (Sissel, Hansman, & Kasworm, (2001). This neglect results in adult students feeling like they don't fit into the campus community; they are aware that they are largely dissimilar to the bulk of the population and not a visible part of the community. The reason for this limited visibility stems from the nature of our capitalist society, a society that has established the adult normative role to be that of a breadwinning employee, not a student. In this society, institutions of higher education are designed to mold youth into such functionaries (Quinnan, 1997). Adults that seek to break away from their normative roles to pursue an undergraduate degree are largely viewed as atypical; students of this demographic have yet to become widely accepted as valuable members of the learning community despite their increased commitment to being actively engaged learners.

Studies in the area of adult student identity coconstruction in intergenerational classrooms have produced several distinct perspectives. A series of studies at 4 year institutions indicated that adult students felt considerable anxiety about their acceptance at their institution, they often questioned their own ability to perform well in comparison to younger students. (Apps, 1981; Chism, Cano, & Pruitt, 1989; Kasworm & Blowers, 1994; Lynch & Bishop-Clark, 1994). This trend is also seen in community colleges, a study by Kasworm (2005) reported that approximately a third of adult students (majors not specified) entering community college self described as feeling self-conscious about their age because of their perception that college is the domain of young adults. Other studies at four year institutions indicated a more positive view of adult student relationships with peers, marked by general acceptance and support (Darkenwald & Novak, 1997; Faust & Courtenay, 2002; Lynch & Bishop Clark, 1993; Stage & McCafferty, 1992; Wilkie & Thompson, 1993). This study investigates the degree to which engineering adult students (at multiple institution types) face otherness. Are adult learners in undergraduate engineering programs inhibited from social integration by their coconstructed identity as others? What types of relationships do adult students have with traditionally aged peers?

Characterizing Adult Student Relationships

Many adult students report feeling invisible and undervalued in the judging environment that is higher education. Subsequently, in efforts to prove their competence and worthiness, a large part of their identity became tied to becoming a “successful student”, an identity marked by being a purposeful learner, competitive, and valuing active engagement in their learning experience (Kasworm, 2006). This identity as a successful student is largely coconstructed through oppositional judgments of their younger, less experienced peers. Several studies of adult students reveal their frustration with the younger student population, highlighting their lack of experience, commitment, and general focus. This prevalent adult view of traditional students as being immature may serve as a major source of divide between adult students and traditional students, preventing them from socially integrating into this dominantly young community. Often adult students are only able to make meaningful connections with students who are closer in age and experience to themselves, a trend that severely limits the scope of their social network.

Kasworm has identified three key frames in which adult students view traditional students. The first frame (as described above) involves adult students viewing younger students rather negatively, subsequently avoiding them or dreading to work with them, believing they are largely disinterested in being academically responsible. The second frame revealed a more positive view of their peers, marked by admiration for their engagement and mutual respect. Adults reported developing valuable friendships with a subset of such students, however they indicated they were limited in their ability to meaningfully connect with all students in this frame. The last frame is characterized by social discrimination and exclusion by traditional students that refused to accept them as colleagues because of their age.

Methods
Semi-structured interviews were used to collect data on the experience of adult undergraduate engineering students ages 25 years and older. Students were recruited from one of three institutes of higher education: A small, private, primarily undergraduate university in the Northeastern United States (PRI), a large, prestigious, public research university on the West Coast of the United States (PUB), and a hispanic serving community college on the West Coast of the United States (COM). All participants met three main criteria: they were enrolled in an engineering degree program, they were at least 25 years of age, and they had prior engineering-related work experience (defined to include such work as manufacturing assembly line, military, technician, construction, and similar work). Table 1 provides an outline of the number of participants interviewed at each institution; the average participant age across institutions was comparable.

Table 1: Demographic Table

Institution	**Total Number of Participants**	**Average Age**	**Age Range**
PRI	5	36.4	26-54
COM	9	37.4	25-55
PUB	10	33.9	26-61

The nature of the relationships between adult engineering students and traditional students was explored as part of a larger study investigating broader themes relating to identity, adult student's conception of engineering as an identity, and adult student's experiences at their academic institutions. Trained interviewers asked participants a series of questions to explore these areas, including the following questions that are targeted towards understanding adult student's connection to their peers and their institution:

- Are there any occasions when you feel especially connected or disconnected to your student peers?
- How similar or different do you feel to a "typical" engineering student at this institution?
- How similar or different do you feel to a "typical" non-engineering student at this institution?
- What does it mean to be an "insider" at your institution?
- How similar or different do you feel from an "insider" at your institution?

All of the questions interviewers asked participants were validated using a trial group of five participants (whose responses are not included in this study) to ensure that the questions were well-posed and balanced. First the analysis focused on the individual adult students case by case, and then a cross-comparison inductive analysis of all participants across institutions was conducted. Several key themes emerged as being relevant across institutions. After extensive comparison of the responses from participants between institutions, it was determined that there were no salient thematic institutional differences in the areas explored in this paper.

Findings

Adult Students Identifying as Others

Participants across institutions described ways in which they perceived not being accepted in their academic environment. Most cited age as creating an obvious barrier to being considered an accepted college student; several describe specific situations in which they feel invisible. A student at PUB expressed:

> *"I'm the invisible man walking through a lot of situations. I remember, when I first showed up, actually to the [college] orientation and they were passing out these little lanyards that say [college] on them, and I walked in, I didn't get one. I noticed everybody else had one, and I walked back and said, what's with the lanyards? Can I get a lanyard? And they said, oh, I thought you were a parent. It's those kinds of things."*

This description was not unique among participants, many described such situations in which they were left out because they were dismissed or slighted because of their age. One PRI participant reflected upon his experience in dealing with being mistaken for a professor or a parent, *"I'm 53 years old and they're in their early twenties...It's just got to be water off a duck's back, and they quickly figure out that you're one of them, even though you aren't one of them. It's not always easy fitting in so you have to be thick skinned enough to not let that bother you."* Some students were not able to be as thick skinned, expressing feelings of shame because of their perception that others consider them to be too old for school. One non-persisting (the only non-persistor interviewed) engineering student at PUB asserted his frustration with this perception, *"I'm kind of embarrassed sometimes to say I'm the oldest cat in the class."* This same student reported that his place in the classroom was challenged by others, he often got the impression that he *"should be somewhere else."*

A significant age gap was not the only factor that contributed to adult students identifying as outsiders in their respective institutions. Participants widely identified added life commitments, such as financial and family responsibilities, to be major barriers to their involvement with campus life and activities. Many describe themselves as being knowledgeable of the resources, programs, and activities offered at their institution, but voice their unfortunate inability to participate due to other, more important obligations. A PRI student states, *"I work full time and have a family so I can't do things. I get tons of emails about things that I wish I could do because there's all kinds of cool things offered, but I just don't have the time for it."* Some adult students expressed clear disinterest in the kinds of social activities offered for students. One PUB student spoke of his limited involvement with a professional fraternity, a type of organization that often leads to invaluable professional connections, because of his disinterest in the immature social environment. He describes himself as being *"very much removed from a lot of that stuff. At 35 years old I have no interest in going and playing night Frisbee [laughs]. It's just not something I'm going to do."*

Disconnect with Engineering Peers

The first frame identified in Kasworm's work, that of adult students viewing their peers as uncommitted, unfocused, and unengaged, was dominantly seen among adult engineering undergraduates. This view largely emerged from their view of themselves in comparison to their peers; the majority of participants highlighted that in this stage of their lives they were intensely motivated to complete school and begin a meaningful career:

> *"At this point of my life I feel the urgency to do everything as good I can do it. So with my school, with my classes, I will do everything perfectly. I have been very focused. Within the next 5 years I want to be a perfect employee; I see that time has been running out and I want to make as much of an impact as I can over the next 25 years of my working career."*

This focus towards making an impact with the time they have left leads to a highly driven, committed, and mature group of students that have little interest in having the traditional "college experience" that their peers are focused on having. It is this principle difference between the groups that is the source of greatest divide. One COM student, when asked why he responded that he felt largely disconnected from his peers, expressed:

> *"I haven't thought it through, but I think my motivations are different. You know, I'm not here to socialize or to have a college life. A lot of friends who went to college when they were younger talk about the college experience and, you know, the stories that I hear about the partying, about the social activities and stuff. I'm not here to do any of those things. So, it's because I feel my objectives are different. I don't know. I'm here to work."*

Participants widely identified as being highly career oriented in comparison with their peers, who they perceived to be less driven and more focused on social activities. Some participants voiced frustration with this, especially in group work, *"A lot of my classmates are younger than I am… let me rephrase that. All of my classmates are younger than I am and many of them don't have the drive to spend the time that's needed or the focus, and I find that frustrating."* This view of younger students comes from the belief that they, unlike adult students who have made the conscious and informed decision to be students, are simply acting according to societal expectations without being fully committed:

> *"Maybe they've been told all their lives that they're going to college and that they're going to get a degree and so that's what they're doing. But they are really kind of just going through the motions, you know. They're here, they're having fun and they don't know what they want and so they're kind of meandering."*

Another salient source of disconnect between adult engineering students and their peers was the difference in professional experience between the groups. This study interviewed adult engineering students with prior engineering experience, a group of students whose experiences and perspectives can improve the classroom culture. It was found that many struggled to connect with those who have little meaningful professional experience:

> *"I'm completely disconnected. I'm old enough to be most of these kid's fathers so I have a lot of practical engineering experience already and it makes it hard to interact with people who don't think like that."*

One adult student from COM who is currently working in an engineering capacity discussed how his engineering experience is a great help to him in the classroom: *"I feel like I have the creativity and the life experience that they haven't had. A lot of things come a lot quickly for me."* This participant mentions his ability to problem solve more quickly than his peers, *"I see that a lot of my peers really struggle to visualize things and to see how things are built, and you know, come up with creative solutions. I feel like... I mean I don't want to sound like condescending or anything, but I definitely will get posed a problem and I could tell my peers are struggling to come up with the solution and I'll have 5 or 6 solutions."* Because of his professional experience, which educators usually assume students lack, this student reported feeling disconnected with his peers because of their struggle with material that he did not find challenging.

The engineering curriculum in particular is notorious for being incredibly academically challenging and competitive. Several participants noted that this unavoidable competitive environment precluded their ability to build meaningful relationships with other engineering students. One COM student noted that he was more easily able to connect with non-engineering students:

> *"I would say I get well along non-engineering student more than engineering students, I think the reason is because in engineering department, it's really competitive. Maybe it's me, but if I'm not the person who has the highest grade, I'm not going to say anything but I will go home and keep thinking that and study even more. I don't really get along too much with my fellow students sometimes...I look at them more as competitors rather than peers. I'm not happy about that, it's just the way it is."*

A PUB participant found that he had a more significant connection with fellow members of a campus dance group as it allowed him to interact with a more diverse group of people in a comfortable, non-competitive environment:

> *"It's a way to express a different part of me, not just Math or Physics, so I can connect in a different way. I feel connected. A lot of the people who go to learn salsa are from different backgrounds, so I can interact with different people with different ideas, because sometimes people from engineering, I feel like they're in a competition. They always talk like the want to be the best, it is a competition all the time."*

Connecting with Traditional Peers

It was found that the majority of adult engineering students, despite being cognizant and self conscious about their identity as others in the youth environment, were able to identify with traditional engineering students because of their shared identity as engineering students. Their single, shared interest in science and engineering is certainly a source of connection; *"We all* *share a common interest in science, generally, and we are all of a like mind in that we tend to be very left brained, mathy type people.*

Adult students generally reported being more easily able to connect to students who they perceived to be like themselves. This often meant forming relationships primarily (or singularly in some cases) with other adult students who have had similar life experiences. However, the bulk of participants described supportive friendships they formed with a subset of younger students who they viewed as equally driven. When asked if she was able to connect with other engineering students, a PUB student responded:

> *"Yeah, when I find someone around my age! [laughs] Oh man, oh you are that old too? That's great! Yeah, because, most students here are really young. Sometimes I feel ashamed of myself. Sometimes I feel embarrassed, letting people I know how old I really am...But I've found a great support group, I've made some great friends, they are not around my age, like teenagers, but yeah, we make good friends. I really appreciate that. The support group is really important in the engineering study."*

This same student expressed her appreciation for the dedication of engineering students, claiming that it motivated her to push herself. *"You can look around the engineering library, it's always full, people always study. People work hard and it's very competitive in the engineering department. It's stressful but in a way I like it because it kind of pushes you to study and grow your knowledge, grow your abilities, so I kind of like that."* This was not an uncommon response from participants, many noted a connection with engineering students and also admiration and awe at their level of commitment for their age.

> *"The serious ones I feel very connected to. So, I would say that, yea, I do feel pretty well connected and similar to the engineering students here. At least the ones that take it seriously. And, I've met some that take it even more serious than myself, and I find them to be very inspiring, you know, I want to be like that. There is some very smart people here...People that are very serious and organized and dedicated and motivated, I find that really inspiring."*

Consistent with Kasworm's second frame, most participants gave similar reports of their ability to form connections with younger students who they perceived to be serious students. Engaging in group work provides a key opportunity for adult students to identify committed students and build relationships with them. One PUB student expresses his appreciation for working with these students:

> *"There are a few people who I've been lucky enough to meet, who are both very bright, almost everybody here is very bright, but these people are not only bright but also apply themselves. I've had the good fortune of being in a group with one or two of these people, and working on some sort of a project or problem and I find that in those situations, yea, I feel connected with them and that's nice."*

Several participants that had decades of technical experience highlighted the importance of being around a group of people of various backgrounds because of the variety of perspectives that brings. They viewed their own experience as an asset and were more than willing to offer advice to their peers. This particular student was able to use his status as an experienced and knowledgeable adult to socially reposition himself from being a complete outsider to a respected and valuable classmate.

> *"I am almost three times the age of most of these people and there is a different perspective you have as you grow older. You learn to identify things that are more salient and disregard the things that are less important. And, without the benefit of that perspective, I find a lot of my colleagues sort of casting about in all of these different directions, which may or may not be productive and that can be really amazing. And… I mean… it's… it's interesting, too! It's an insight into the way that people my son's age, for instance, approach things. And if you hang around people that are in the same age group all the time, you don't, you don't, you don't get to see that because you're all sort of coming from the same place. And, and… now, the other side of that is, the good news is that occasionally I've been in a position where I'm able to help. And, sometimes, and I find really that I am not ostracized as I thought I might be, and my classmates do listen to me, and occasionally will even do some of the things that I suggest. And in that case, in that situation, I find myself mentoring, somewhat, and that's very rewarding."*

Conclusion/Recommendations

Adult engineering undergraduate students largely identified their general perception of being viewed as another in their academic environment, revealing instances when they were dismissed or slighted because of their age. These students explained their inability to become highly involved in campus activities due to other, more "grown up" responsibilities they must prioritize. Consistent with work by Kasworm, adult students were found to have complex relationships with traditional students. Adults generally viewed themselves as more committed learners, more experienced, more career focused, and less interested in social involvement than most of their younger peers. However, a subset of these traditional students they found to be highly intelligent with an admirable desire to succeed. The third frame in Kasworm's work, that characterized by openly hostile rejection by their peers, did not surface in this study.

With the information gained in this study we begin to provide recommendations for educators and administration to promote successful social integration of this important demographic. Educators must first be aware of the presence of adult students and subsequently be perceptive of the types of relationships forming in today's increasingly intergenerational classroom. Because of the notoriously competitive and rigorous nature of engineering programs, educators must actively promote collaboration rather than competition. Collaboration in the form of group work and team projects in an excellent way to integrate adult students into the learning community as it provides them the opportunity to work closely with their peers, form friendships, and also showcase and utilize their professional experience. Providing students with a platform to use their experience is key to promoting inclusivity. Educators must work to highlight the experience of adult students, doing so will not only validate their position as valuable students but also greatly benefit the overall classroom culture. Last, since adult students are more experienced and significantly more career focused, more opportunities for advanced professional development must be provided.

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Role Identities and Social Integration among Adult Engineering Undergraduate Students

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Abstract

A maturing engineering workforce in the US leaves many opportunities available for aspiring engineers. However, colleges are not graduating enough engineering students to fill all job opportunities with qualified engineers despite high interest from college-bound high school seniors. Adult undergraduate engineering students represent a crucial element in fulfilling the need for engineering graduates, and they face challenges that are unique to their demographic. Social integration of adult students into their academic communities is a key predictor of persistence in degree programs, and characterizing the social environment of multiple institutions can aid prospective adult students in choosing the college that is the best fit for them. This study was carried out using semi structured interviews conducted at three distinct academic institutions: a community college, a small private college, and a 4-year public university, to examine the role identities of adult engineering undergraduate students in each academic environment. Data revealed key differences in the identity trends of students at each academic institution. Community college students claimed multiple responsibilities in addition to their academic workloads. Public university students exhibited a schedule solely committed to their studies. Private college students were very dedicated to their family roles and commitments and considered these more important than school. These social distinctions between student populations from each academic institution illustrate the diversity of nontraditional students and the challenges they face. This makes social integration with a dominant traditional student population challenging due to differences. By establishing nontraditional student communities within colleges and implementing policy that is specifically formulated to aid nontraditional students to academic success, we can hope to foster social integration and in turn positively influence their persistence in college engineering programs.

Introduction

Engineers are sorely needed as we look into the next decade as the current engineering workforce ages into retirement. College engineering programs are not graduating nearly enough qualified engineers into the workforce despite high interest in the field by incoming freshmen. In a 2013 report published by the US Department of Education, 48% of bachelor's degree pursuing students and 69% of associate's degree pursuing students left their chosen STEM field by changing majors or dropping out from their institution (Chen, 2014).This significant exodus of students from STEM fields leaves behind a reduced pool of degree candidates unable to satisfy the need for engineers in the professional workforce. The need for engineers stems from a higher- than- average job- growth rate in the engineering industry coupled with those retiring from STEM careers (Sargent, 2014).

It is clear that persistence is a main obstacle to replenishing our engineering workforce. Much work is being done to attempt to understand the needs and challenges of the traditional engineering student as most students in engineering programs fall into the traditional student classification. We classified traditional age students as those who were between the ages of 18-22 and entered college straight from high school. For our study, nontraditional students were defined as students who were age 25 or older and were working towards a bachelor of science degree in engineering. Many of the typical characteristics of non-traditional students were observed in the participant group: financial independence, having dependents, part-time college enrollment, full-time and part-time employment, along with delayed entrance to college. The non-traditional adult student age minimum was set at 25 to avoid working with traditional students who decided to stay in school longer (i.e. super seniors).Overlooking the experiences of engineering non traditional students means that we are discounting a pool of potential engineers that we can aid to become qualified ones.

So how large is this pool of nontraditional students? Currently, adult students make up 37.6% of the student population at 4 year institutions in the United States and 40.3% of the population at 2 year institutions in the United States (Ciston, Hoang, & Mikel 2015). Adult student enrollment rates are increasing on par with the rates of their younger, traditional counterparts, and the rate of increase of adult enrollment in college is expected to outpace the rate of increase in traditional age student enrollment (Digest of Education Statistics, 2009). However, little work exists that studies the engineering education experience of such a large student group. A report from the Multiple-Institution Database for Investigating Engineering Longitudinal Development indicates that adult engineering students have a lesser graduation rate than their traditional engineering peers (Bushey-McNeil, Ohland & Long, 2014). This implies that the adult engineering student body experiences challenges specific to their demographic. Adult students are more likely to be married, have dependents, be financially independent, be enrolled part time, and be employed (Bushey-McNeil et al., 2014). Adult students enrolled full time are more likely to attend community college than a public 4-year college (Choy & Premo, 1995). Working full time and going to school part time are both factors that have been independently linked to lower rates of persistence and degree attainment (Berker & Horn, 2003; Berkner, Cuccaro-Alamin, & McCormick, 1996).

By investigating the identities embodied by students of various college environments (community college, public universities, and private universities), we can begin to understand the social makeup of nontraditional student populations of each institution. Armed with these observations, we can promote social integration, a key factor in nontraditional student persistence, by identifying what kinds of students attend an institution type as well as the kinds of students who are being left out of such academic environments.

Background/ Literature Review

Adult engineering undergraduate students face not only the challenges associated with difficult coursework, but also the added challenges of having conflicting identities. Identities as parents, providers and employees make being an engineering student difficult (Berker & Horn, 2003). It is essential to understand how engineering students at various institutions self-identify during this time in their life and what goals they are making for themselves as students and future professionals. With a complete picture of what goals students are striving for and considering what identities they hold, we can begin to explore the similarities and differences of adult students across different academic institutions.

Multiple Identity Theory

A previous work shows that a person's identity is not one-dimensional, rather it is a complex network of interrelated identities rooted in social interaction (Jackson et al., 1981). All at once a person can be a student, a chef, a spouse, a parent, an athlete, a Republican, a feminist, an employee and a friend. A person does not hold the same level of commitment to every identity he/she carries, rather these identities fall into a hierarchy.

Adult Student Learning Experience

Past work has shown that adult students are likely to have conflicting identities (Choy & Premo, 1995; Berker & Horn, 2003). These students are more likely to have responsibilities as parents, providers and spouses that conflict with their identities as students. These multiple identities make it that much more difficult to interact and understand their traditional student peers who usually have limited identity understanding due to a more simplified lifestyle. We cannot simply approach nontraditional student retention and engagement in the same manner that is applied towards traditional students. Current efforts generalizing traditional student policy toward the entire college student population (traditional and nontraditional alike) has led to nontraditional student dropout rates twice the dropout rate of their traditional counterparts (Brown, 2002).

Student Persistence (Traditional vs. Nontraditional)

As mentioned before, traditional student behavior and performance has drawn plenty of study and research. Persistence is an important part of this effort. It has been broken down to several factors which include academic integration, social integration, teaching and facilities, prior qualifications, individual attributes, family attributes, and individual circumstances (i.e. debt, family events). Most of these factors are self-explanatory, but the two most influential factors are academic and social integration. Academic integration composes of grade performance, personal development, academic self-esteem, subject enjoyment, study enjoyment, identification with academic values, and identification with the student role. Social integration, on the other hand, depends on whether you have friends or not, personal contact with academics. Whether a student persists or not is entirely dependent on the degree of academic and social integration (Draper, 2008). However, the same factors do not influence nontraditional student persistence. Statistical analysis shows that when it comes to nontraditional students, social integration is the most important factor that affects their persistence in college. Two major differences between traditional and nontraditional students explain why social integration is the only factor worthy of note when it comes to student persistence. Nontraditional students typically do not reside near campus which denies them environments that make social integration easier. When it comes to academic integration, findings have found nontraditional students to be much more strongly committed to their schooling than their traditional peers therefore academic integration is a less significant factor when it comes to their persistence. The reason why they go back to school is strongly rooted in academic integration. Nontraditional students go back to school because they desire to learn and advance their professional qualifications (Ashar & Skenes, 1993).

Social Integration

Social integration is important to persist in an environment. This is especially true in a challenging environment such as college where the massive population can make one feel small and lost in the crowd without the proper support system. As mentioned, nontraditional students are usually denied opportunities to interact with both their nontraditional and traditional peers. It is from these rare opportunities in which they could construct their social support system. Nontraditional students relate best with those who come from their background and circumstance. (KASWORM, ZHANG). With inability to access an environment with their nontraditional peers, nontraditional students are limited by circumstance usually to the classroom where current classes are dominated by traditional students. Nontraditional students can be considered a non-homogenous group due to the diverse backgrounds and identities embodied by such students. This makes it difficult for them to connect with traditional students who are relatively homogenous (Brown, 2002). Traditional social integration is measured through student-faculty interactions, student-counselor interactions, and student-student interactions. For the purpose of this discussion, we will focus on interaction between students and their peers. A study performed on a minority group in the University clarified the definition of social integration to mean the extent to which the social environment affords opportunities for minority students to interact with those who share their background and culture. Clear communication and support from faculty, the presence and availability of other peers, and activities that brought together said peers, were the best indicators of social integration.

Social integration occurs when peers are able to relate and connect through relatable circumstances and experiences. Such relations can arise from similarities in attitudes and demographic attributes (i.e. race, age, education) (O'Reilly, Caldwell & Barnett, 1989). It is through this common understanding in which mutual respect can be established and social integration can be achieved. By understanding the multiple identities held by a student population, we can piece together its social profile to allow nontraditional students to make an informed decision about how they would be able to integrate themselves into the school's social network. Social integration is built upon many connections between many similar individuals and it is through these connections that a community can be built upon.

Methods

Our multi-institutional study was carried out with the goal of understanding the social makeup of each college type. We wanted to note the responsibilities and identities of students that were attending these colleges as well as underline the absences of certain types of students at each college institutions. Data was collected from a community college (COM), a small private university (PRI), and a large public university (PUB). Semi-structured interviews were conducted with participants that were engineering undergraduate students above the age of 25 with prior engineering work experience.

Context

PRI is a private institution located in the Northeastern United States with more than 4600 undergraduate students. Students over the age of 25 comprise 19% of students in the undergraduate engineering programs, which offer day as well as night classes. Of the students enrolled in engineering programs, 37% self report as White, 10% as Black or African American, and 5% respond as Hispanic.

PUB is a public university located in the Western United States. As of fall 2012, PUB enrolled more than 25,000 undergraduate students. Among undergraduates, about 750 were enrolled part-time and and 25,000 full-time. The average age of undergraduates is 21 years, with 7% aged 25 or older. A majority, 79%, of undergraduates are “in-state” from the state of the university, with 10% coming from countries other than the United States. Among domestic students, 44% identify as Asian/Pacific Islander, 32% White, 14% Hispanic, 4% African American/Black, and 1% American Indian/Alaskan Native. The entering class of new undergraduate students was composed of two thirds first-time freshmen and one third transfer students. PUB offers Bachelor’s degrees in nine engineering disciplines.

COM is a community college and a federally designated Hispanic Serving Institution on the West Coast. During the 2011-2012 academic year, the College enrolled 10,965 students, with Hispanic students comprising 35.5%, Caucasians 32.6%, Asians 8.1%, African Americans 3.9%, American Indian/Alaska Natives 0.3%, Filipinos 3.6%, Pacific Islanders 1.7%, multiracial 9.3%, other 4.9%. Approximately 21% attend college full- time. COM’s mission is to ensure that students from diverse backgrounds achieve their educational goals by providing quality instruction. COM’s Engineering Program is a transfer program that offers a comprehensive set of lower division engineering courses needed to transfer to any four- year engineering program in any field of engineering. Every year, about 30 students complete the program and transfer to four- year engineering programs all over the state, as well as out- of- state.

Participants

Participants were adult students (age 25 and older) with prior engineering work experience that were currently enrolled in an undergraduate engineering program.

Institution	Total Number of Participants	Average Age	Age Range
PRI	5	36.4	26-54
COM	9	36.7	25-55
PUB	8	34.5	25-55

The average ages and age ranges of participants across institutions are comparable. Out of 22 total participants, only 3 female engineering undergraduates were interviewed, exclusively at PUB. Participants were made aware of the study via campus flyering and mass emails. Once a potential participant contacted the principal investigator to indicate their willingness to participate, he/she was directed to complete a pre-qualifying survey to determine eligibility. In this survey participants were asked about their age, degree program, and prior engineering-related work experience. Responses were evaluated and qualifying participants were contacted through email. Interviews were scheduled at the convenience of participants. Participants received $25 for completion of the study.

Instruments

Semi-structured one hour interviews were conducted with participants at each separate institution by trained interviewers. Before the interview started, participants consented to being interviewed and were informed of the goals and motivations of the study along with their rights as participants. During the interview participants were asked questions regarding identity, motivation and future plans. Using the same method as described in the multi-institutional study by *Matusovich et al* (2011), participants were asked to generate a list of ten nouns or phrases that describe who they are. They were then asked to rank this list in order of importance for the purpose of identifying commonalities and differences between adult engineering students of different institutions. From the interviews, audio recordings were obtained, transcribed, encrypted for participants' confidentiality, and analyzed using thematic analysis and multiple identity theories. After the interview was completed, participants were asked to complete an optional demographic survey that asked about employment status, gender, enrollment status, degree program, marital status, if they had dependents, etc. The purpose of completing this survey was to gain a better understanding of how student demographic profiles vary amongst community colleges, large public universities and small private universities.

Analysis

Following the same method as *Matusovich et al*, the nouns provided by participants were grouped into categories and assigned points based on their ranked importance. The most important noun was assigned 10 points, the least important noun 1 point. For each participant we summed the total of points within each category before looking for patterns among institutions. The identity categories used are listed and defined as follows:

- Academic: identity related to a role in an academic setting such as student, learner, etc.
- American/Immigrant: calling oneself an American, immigrant or international student
- Athlete: association with a member of a school, internal or club team, team or just "athlete" in general
- Character Traits: identity roles that describe ways of being such as helper, loner or giver
- Engineer: specific mention of an identity as an engineer (note these also count under the even broader category of "professional")
- Engineering Character Traits: identity roles that are not specifically professional linked but are well established traits of engineers such as creative, problem-solver etc.

- Potential Engineer/Engineering Student: mention of being an engineer in the future or working towards becoming an engineer
- Ethnicity: ethnic identity such as Hispanic or African American
- Family: identity associated with family relationships such as son, aunt, sister, etc.
- Friend: identification with being a friend
- Geographic Region: identify as coming from a specific region such as Texan or Chicagoan
- Hobbyist: identity role related to an enjoyed activity such as photographer, fisherman, hunter
- Leader: specific role as a leader or follower (note these can also count in "Professional" if used in the sense of a career)
- Political: identification with a specific political view such as democrat
- Professional: identity descriptors related to career roles such as engineer, builder,employee
- Religion: identifying one's religious affiliation such as Catholic or Christian
- Romantic Partner: identification as a romantic partner such as boyfriend or girlfriend
- School: identifying with the specific school or school mascot such as Badger or Husky

Results

Demographic Analysis

Participants across institutions were all within the same age range (25-55) and had average ages in the mid 30's. Data for the employment status, course load, marital status and number of dependents are presented in Figures 1, 2, 3, and 4.

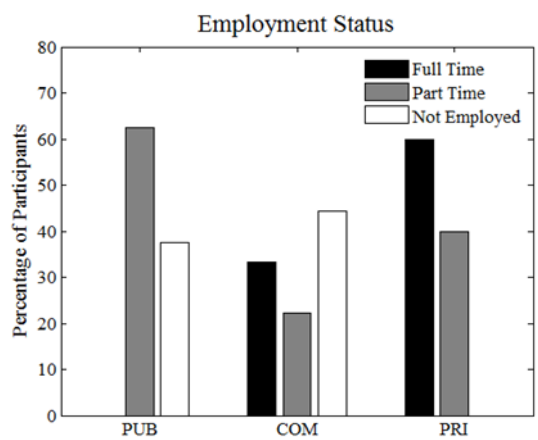

Figure 1: Participant employment status

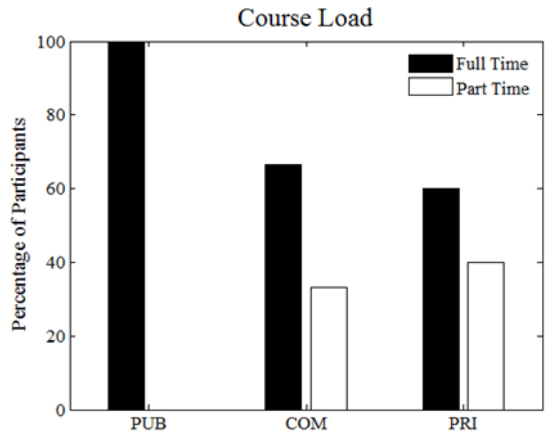

Figure 2: Participant course load

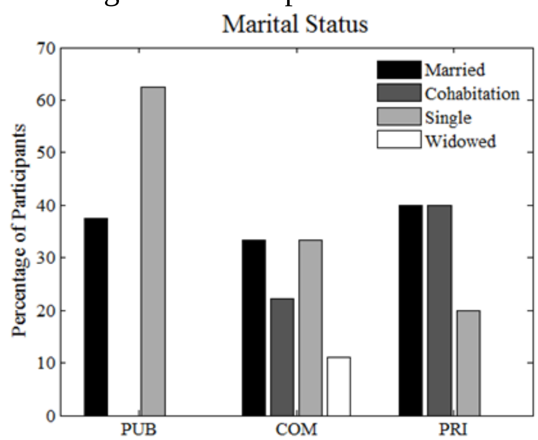

Figure 3: Participant marital status

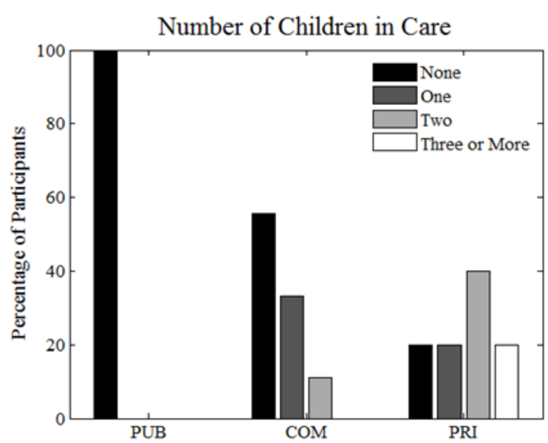

Figure 4: Participant dependent status

Several differences are observed across the three institutions. PUB participants displayed an academic-centric lifestyle. All PUB participants identified as full-time students. None worked full-time jobs in parallel with their academic commitments. Rather, a majority of PUB participants worked part-time and the remainder of participants chose not to work while in school. The majority of PUB students are single while no PUB students claimed any dependents.

A majority of COM participants are enrolled as full-time students. Employment obligations are split among COM participants but the highest percentage of COM students were unemployed. COM participants were also split on relationship status with the highest percentages of COM participants were either married or single. Most COM participants did not have dependents, however, of those who did, no COM participant was responsible for more than two children. It is important to note that of the COM participants that did have children, the majority only had one child in their care.

PRI students were all employed to some degree. 60% of PRI students were employed in full-time jobs while 40% had part-time jobs. The 60-40 split carries over to the percentage of students that were enrolled in school full-time versus those who were enrolled part-time. PRI students had various marital statuses and number of dependents, none of which dominated the others in responses. To this degree, PRI had the most variety and spread in responses in comparison to PUB and COM.

Nouns Analysis Results

The results of the selective coding process of the participant generated nouns lists are presented in Figure 5. Only the most universally identified identity categories are included.

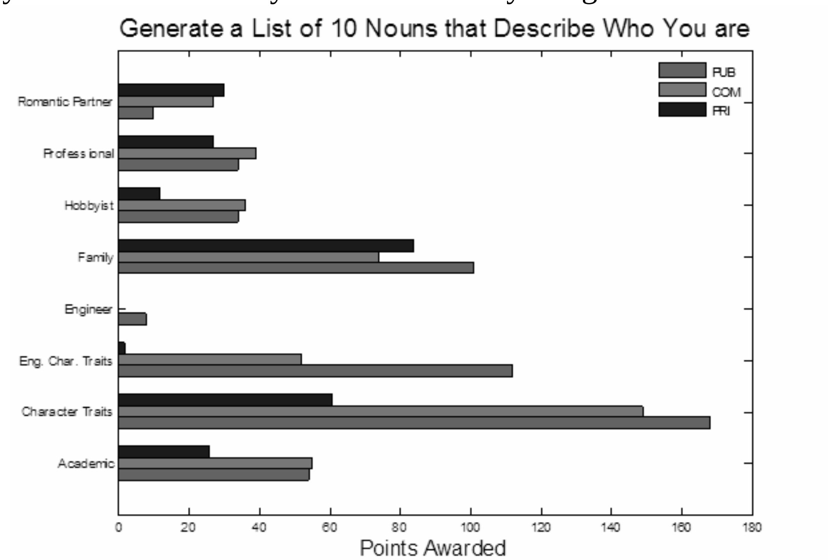

Figure 5: Self-Identified Nouns

PUB participants identified with all the categories listed in Figure 5. The top three noun categories mentioned were character traits, engineering character traits, and family. The bottom two categories were engineer and romantic partner. The top three categories dominate the scoring with respect to the other noun categories. This indicates that PUB participants defined themselves primarily through their character traits, engineering character traits, and their family.

COM participants had more evenly distributed scores after their top two scoring categories. Their top three noun categories were character traits, family, and academic. The least mentioned categories comprised of romantic partner and hobbyist. Their scoring distribution was more varied implying that COM participants took on a more well-rounded lifestyle.

PRI participants were the only study group that did not place character traits as their leading nouns category. Instead, character traits comes in second place between family and romantic partner. It is important to note that family and character traits dominate the scoring for PRI participants which leads to a very close score distribution between the remaining categories. The lowest scoring categories were hobbyist and engineering character traits. PRI participants had the most evenly distributed scores of the the three institutions; this is a reflection of how balanced their lifestyle is and how they do not overly focus on some areas of their life.

Discussion

Demographics Comparison

Analysis of the the demographic surveys collected show important differences between students of different institutions. According to a 2003 study funded by the Department of Education, students who list being an employee as their primary activity are more likely to attend community and private institutions rather than public universities (Berker & Horn, 2003). This study also showed that employees who study are more likely to be enrolled part- time, be married, have dependents and be financially independent. These conflicting identities make being a student at a competitive university challenging as they need to keep up with peers with fewer responsibilities.

These trends are consistent with the demographic profiles of students at each institution that were interviewed in our study. The differences between the types of students attending each institution can be partially explained by the types of support services available at each institution. COM participants noted the availability of evening classes which accommodated their work schedules while PRI offered evening degree programs. Participants at PUB highlighted that such evening programs did not exist and that being a student at such a competitive university was overwhelmingly time- consuming. This lack of accessibility and public awareness of adult student support programs at PUB has attracted a very specific student population who have limited responsibilities outside their academic obligations; the majority of PUB participants were not working full time, single, and childless.

While PUB participants had no parenting responsibilities, the same cannot be said about their peers at COM and PRI. Seven parents were interviewed at COM (3) and PRI (4); none were female. Of the fathers interviewed, many indicated that being a provider for their family was a large motivator; this identity as a provider is in line with their pursuit of a financially stable career in the long term. It is important to note that none of the PRI or COM participants were female. Also note that the number of participants at each location was not uniform (5 at PRI, 8 at PUB, 9 at COM). The lack of parenting non-traditional students suggests that PUB and institution similar to it foster an incompatible environment to students with parenting obligations.

Nouns as a Lense for Understanding Social Makeup

Nouns falling under the character traits category scored in the top three for all three collegiate institutions. Family scored in the top three as well for all three populations. These trends are expected because people tend to describe themselves by alluding to their character habits as well as their clearly established roles in their family. However, past these consistencies, we observe differences in the responses from each institution.

For PUB, we observed that engineering character traits landed in the top three scores. This is an indicator that PUB participants already have begun the process of identifying with being an engineer. Some PUB participants have outright described themselves as engineers; this was not observed with any participants from COM or PRI. One reason explaining this anomaly can stem from the idea that PUB students entered PUB with an identification with engineering. Many PUB nontraditional students are transfers from two year community colleges and successful transferring into a formal engineering program can provide students with the confidence and credibility to describe themselves as engineers. The lowest scoring category of romantic partner is consistent with the demographic data of PUB students which saw the majority being single as well none having any dependents. This is definitely an area that PUB can focus, to foster a community that attracts students that not only are dedicated to their studies but also developing their social life whether that be through relationships, dependents, or a combination of both.

COM students had the most diverse social makeup. The relatively even distribution of noun category scores outside the top two scores indicate that COM students maintain multiple responsibilities that include being a student which they deem as important as their other commitments. This observation makes plenty of sense because COM students are at an early stage in their post-secondary education. Many have families and jobs to tend to. Therefore, prospective students who are unable to devote their full attention to academics would do well to consider COM-like academic environments where they can relate easily to peers circumstantially and have a support system that understands their multi-faceted lifestyle.

PRI participants' top scoring category excluding family and character traits was romantic partner. Students in PRI value their relationships highly as evidenced by how important romantic roles are to their description of themselves. PRI's structure must allow students with relationships to balance their academic commitments with personal time with their loved ones, thus it draws students who view college as only an academic environment. This is clearly different from traditional students who approach college as a lifestyle as they live near campus and establish their social network through college-related activities and acquaintances. PRI students scored lowest in engineering character traits and hobbies. This indicates that PRI students are solely focused on their formal academic program and devote the remainder of their time to their personal life. Although PRI offers many extracurricular activities for its students, it seems that involvement in such activities is the exception and not the norm for nontraditional students. Based on their high scoring in the nouns categories of romantic partner and family combined with their demographic information, PRI students have structured lives that allow them to engage only in the academic learning aspect of college.

Comparison to Traditional Students

While it is ideal for nontraditional students to interact with their peers, they will still be surrounded by traditional students. Social integration can be achieved between these two contrasting populations, but it is more difficult due to incompatibility in life experience and age. Family has been deemed important equally by all students across the institutions surveyed. This is not surprising because familial roles and identities are clearly defined and have been embedded in these students' lives from the beginning. Romantic partner was mentioned by traditional students as well. While this could be seen as a similarity in the sense that nontraditional students also mentioned romantic partner in our study, the degree of importance was different. For traditional students, their romantic partners are usually boyfriends and girlfriends while for nontraditional students, their romantic partners can be their spouses or long-term significant others.

The differences between responses of the nontraditional and traditional students were stark. For example, traditional students identified with their nationality (American or immigrant) in their nouns listings while nontraditional students did not mention such identifications. Another noun category that was brought up frequently by traditional students was friend. This was scored as equally important across all three institutions. With nontraditional students, "friend"-related nouns were not mentioned at all. This absence further supports that idea that nontraditional students have structured lifestyles and that they separate their personal and academic commitments. Traditional students, on the other hand, essentially live in the college environment, going to school and living near/at school. This arrangement makes traditional students lives much simpler in comparison to the lives of nontraditional students as well as making their college experience a combination of social and academic development. Geographic region was mentioned by traditional students as well but no nontraditional students brought any nouns related to this category. Usually, we see traditional students depart from their hometowns to go to school far away and thus, the need to identify where they came from comes up. With nontraditional students, they typically choose to attend a school that is closest to where they currently reside (or work) because it is simply more convenient for them. Through this thinking, it makes perfect sense that nontraditional students would not identify their geographical region because to them, it is not a differentiator.

Conclusions/Future Studies

The goal of this study was to investigate across multiple institutions what personal identities students take. Grounded in multiple identity theory, this study aims to discover how conflicting identities of adult undergraduate learners affect their choice in institution and how they resolve their conflicting identities to succeed in the rigors of an engineering program. By understanding this process, we hope to assist in developing methodology to improve recruitment and retention of adult engineering students by strengthening the development of identification with engineering in this important demographic.

Non traditional students from all institutions viewed family as equally important, with family being mentioned frequently by all three student populations. They were also all united in describing themselves through words that described their character. A common demographic trend identified for all three student populations was that the majority of participants at all three schools were enrolled as full-time students. Despite their responsibilities outside school, nontraditional students are fully committed to their schooling.

Each institution has differences however. It is these differences that impact the social integration of adult students, with important implications for student persistence. PUB students frequently described themselves with engineering character traits; some also went as far as to declare themselves outright as engineers. However, romantic partnerships was unimportant to PUB students with nouns related to romantic relationships mentioned minimally because most PUB students were single and without dependents. COM students had relatively evenly distributed scores suggesting a balanced life between academics and personal commitments. This makes COM an ideal academic environment for potential students who have busy schedules and have a need to balance multiple commitments beyond their academic degree programs. PRI students value their romantic partnerships highly and do not consider their hobbies as important as other commitments. We can observe that nontraditional students that would be a good fit for PRI would view college as a means to learn and not a lifestyle since many PRI students have other commitments outside of their academics.

The study draws its conclusions based on a relatively low, unequal sample of the three surveyed institutions. Future studies will address this limitation by gathering more engineering identity interviews at each institution in order to achieve an equal number of participants across all institutions. Because of the lack of diversity of the data sample, future work in this area should focus on studying how female nontraditional students', especially mothers', social hierarchy differs from those of male nontraditional students. Future work can also profile the social makeup of nontraditional students at other types of colleges (i.e. 4 year public universities in other regions of the US, for-profit colleges).

Recommendations

Our data suggests that an academic environment such as PUB is less likely to have inclusive participation of students who have competing responsibilities such as that of parent and employee. The establishment of evening classes, student-parent centers, student-parent policies around reduced course load or leaves of absence, student health insurance that allows for dependent coverage, and daycare centers for children of students are some options to create a support network for engineering students with children. It is worth noting that the public institution in our study does have a wide range of services to support student parents, including student-parent grants, daycare centers, a student-parent center, and options for reduced coursework during childbearing. Better awareness about such programs could serve to attract, retain, or support adult engineering students during their degree work, but it is worth considering that these services alone may not be sufficient to make PUB's rigorous academic environment the right choice for all adult student parents.

Overall, all institutions can make improvements to aid their nontraditional students. We recommend that nontraditional student communities be established, so that a social space is available for nontraditional students to interact with their peers outside the classroom. While it may be difficult to gather nontraditional students in such a community, we can make this offering more accessible by packaging the community as a class. A short one-unit course may motivate nontraditional students to engage in a peer community while simultaneously giving them academic credit for their efforts. For students who would like to reside on campus in a dorm-style environment, a residential floor could be implemented to allow nontraditional students the bonding experience of dorm life with their peers. In order to accommodate student-parents, family-friendly apartments or dorms should be introduced as a way for student-parents to keep their family close while having access to the support they need in their academics. All of these recommendations revolve around how important it is for nontraditional students to be a part of a community that they can feel comfortable in.

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Assessment of an Undergraduate Mechanical Engineering Design Capstone Course

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Abstract

Capstone design courses allow mechanical engineering students to utilize all prior analytical learning to explore engineering design, which acquaints undergraduate engineers with the real-world engineering practice that awaits them after graduation. However, due to the open-ended nature of design projects, it has proven difficult to assess student learning in capstone courses. Additionally, most of the existing literature on evaluation of capstone courses focuses on technical writing or oral presentation skills, and rigorous studies on evaluating pedagogies to support the learning of the engineering design process itself have been mostly neglected. The goals of this study are to implement and evaluate measures to improve engineering design education in an undergraduate Mechanical Engineering (ME) program and to assess achievement of ABET-guided ME departmental program learning outcomes as a result of student participation in the capstone course. To achieve these goals, we utilize a triangulation approach, combining data from 1) student surveys and self-assessments, 2) rubrics to regularly assess student progress on the design process, and 3) focus group interviews with students. Each assessment method has been carefully designed utilizing information from the existing literature on survey and rubric design. Based on these data, we identify shortcomings of the capstone course as taught in year 1, devise and implement specific improvements to address these shortcomings, and study the effects of these improvements over the course of one academic quarter in year 2. Our study identifies key areas for improvement in the capstone course; a few examples are provided here. Students in year 1 wanted more guided feedback on their design projects. We responded by implementing weekly rubrics to provide feedback to students in targeted areas. As a result, 65% of students who received such feedback responded that it improved progress on their projects during the quarter. Additionally, of the students in year 1 who were unhappy with the balance between creativity and structure in the class, 66% wanted less structure in the class, specifically with regards to writing multiple intra-quarter formal reports. To address this, we replaced reports with informal Living Notebooks. Students in focus groups unanimously agreed that the more open nature of the course was extremely helpful in making progress on their projects, and that the Living Notebooks were essential to helping them organize and share information with their teams. Finally, one third of students in year 1 expressed difficulties in working on teams due to intra-team conflicts. As such, we implemented a mid-quarter peer review to allow students to assess peer performance while providing time to alter team dynamics for the latter half of the course. This study reports on the effectiveness of these improvements to the capstone course piloted in this study.

Introduction

The capstone design course is an integral part of many engineering curricula at the university level. Most existing literature on assessing student learning in such courses focuses on assessing student abilities in report writing, presentations, and communication (Norback & Utschig, 2010; Simpson, 2004). While there are some comprehensive studies that aim to capture student understanding of the engineering design process (David et al., 2002; Trevisan et al., 1999; Reeves & Laffey, 1999) and other skills that students are expected to pick up during a capstone design course, they are few and outdated. Additionally, the optimal method for teaching the open-ended and creative capstone course has not been discussed in great detail. This paper addresses these shortcomings by providing support to students in targeted areas identified as weaknesses in the existing capstone course, through formative assessment, as well as tracking student learning in key learning outcomes. Specifically, this paper presents the results of an assessment activity to improve student learning in the Mechanical Engineering (ME) Department's capstone course, a required senior-level series over fall, winter, and spring quarters at the University of California, Santa Barbara. In order to determine the most effective way of teaching the design capstone course, students in year 1 were surveyed to determine shortcomings of the capstone course, and a series of improvements were developed and piloted over the course of the fall quarter in year 2. The suggested improvements as well as their effectiveness are discussed in detail in this paper. Additionally, this paper presents an assessment of achievement of ABET-guided learning outcomes in the ME design capstone course, using both direct evidence and by tracking student self-reported learning at the beginning of the capstone course, and presents the changes in learning after one quarter of the capstone course.

Methods

Graduating seniors in the undergraduate ME class of 2015 who took the ME design capstone course were surveyed at the end of spring 2015 to identify shortcomings in year 1 of the capstone design course. Of the 88 students enrolled in the course, 37 submitted responses to the survey. From this survey, a series of shortcomings were identified and improvements were piloted in year 2, over the fall 2015 quarter. Students enrolled in the fall quarter of year 2 of the ME design capstone course were surveyed at the beginning and end of the quarter, and participated in focus groups towards the end of the quarter. Students in year 1 were awarded extra incentives for participation in the surveys, which accounts for the much higher response rate in this year. Of the 71 students enrolled during year 2, 69 students submitted responses to the surveys, and 14 students participated in focus groups. Each of the surveys created for this course were carefully designed incorporating features outlined in the literature on survey design, especially in the context of using surveys for assessment and student self-evaluation (Prus, 1994; Adams, 2000). The surveys featured both open-ended and closed-ended questions. In places where survey percentages do not add up to 100%, this is due to rounding.

Structure of the Class

The year 2 ME capstone course involved in this study is the first in the capstone series, held over one academic quarter (10 weeks). Students choose their projects and project teams in the first week. The 16 projects are split into three main categories – 9 industry projects, which are sponsored by an engineering company, 5 academic projects, which are based on research by a faculty member at UCSB, and 2 competition projects, both of which are working on the SpaceX

Hyperloop Pod Competition. Students are given specific milestones to work towards during the quarter, as seen in the weekly schedule provided in Appendix A. The instructor of the course holds a lecture once a week that is optional for students to attend, although they are strongly encouraged to do so. The students also have weekly "cohort" meetings, during which they meet with their faculty advisor, a graduate student teaching assistant (TA), and another project team from the capstone class, for one hour. The students prepare short PowerPoint presentations for the cohort meetings and receive feedback on their progress and suggestions for next steps from the advisor and TA during these weekly meetings. The students are required to give a formal presentation on their projects at the end of the first quarter of the capstone course in front of an audience of their peers, the instructors of the course, and the project sponsors, as well as to submit a final report.

Shortcomings of Year 1

Grading

In year 1, the grading was primarily based on judgment of the faculty members involved with the course. At the end of the spring quarter, students in year 1 were asked in a survey to recall if at the start of the year they were clear on how they were going to be graded. Their responses are shown in Table 1.

Table 1. Clarity of how students were graded before they started assignments in year 1

Response	Response rate
Very clear	43%
Somewhat clear	46%
Not clear	11%

Although 43% of students felt that the grading process was very clear, the majority of the class felt the process was at least somewhat unclear. The students who felt that the grading process was not always completely clear to them elucidated their reasoning in their comments. One student who felt that the grading process was "somewhat clear" commented that "grading at times felt very arbitrary, reflecting the general feelings of the teaching team rather than reflecting an objective grading process." Another student mentioned that "some of the documents and requirements [of assignments] were very rough and conflicting." These sentiments indicate the need for a more rigorous and transparent grading process. One student commented specifically on the feedback received, mentioning that they "never received any graded assignment back, only a grade and some rough, hand-wavy verbal comments."

The student comments indicated two clear trends: 1) it was unclear to students why they received the grades they were awarded, and 2) they did not receive enough feedback on their performance during the quarter. To address the first concern, a rigorous grading rubric was designed for grading the teams' final presentations and reports, given in Appendix B. This rubric is discussed in more detail in the section on assessment of students' achievement of ABET-guided learning outcomes. To address the second concern, feedback forms were introduced in year 2, which were filled out by the TAs after the weekly advisor meetings. The features of the feedback form, and its effectiveness, are addressed in the section on course improvements piloted in year 2.

Creativity

Engineering design at the professional level is a balance between creativity and technical prowess. At the end of year 1, students were asked in a survey to identify features of the capstone class that discouraged their personal creativity. As seen in Table 2, 46% of students chose assignments as the feature that most discouraged their personal creativity. In their survey comments, students indicated that they were referring specifically to the number of reports during the class in the fall quarter in making this choice, which they felt were far too many. In year 1, students were required to submit several formal reports during the quarter to convey their progress on their project. Students expressed that the multitude of reports left "little time for us to actually make progress on our project, resulting in more of a time crunch later on." Another student expressed a desire for "a philosophy more oriented to project completion" within the class.

Table 2. Course features that discouraged the personal creativity of students

Course feature	Response rate (year 1)
Assignments	46%
Available resources	19%
Fellow group members	16%
Grading	14%
Instructors	0%
Project advisor	16%
Structure	5%
Other	0%
No feature	38%

In response to the students' complaints, the instructors chose to replace the required formal reports in the first quarter of the course with an online Living Notebook. The features of the Living Notebooks as well as their effectiveness are discussed in more detail in the section on course improvements piloted in year 2.

Team Dynamics

At the beginning of year 2, students were asked in an open-ended survey question to name challenges they had previously faced in working on design projects. Of the 52 students who responded to this survey question, the students' most cited challenges were issues pertaining to working on teams (such as unequal division of labor, issues with communication, and mismatching schedules), noted by 38% of students. To address this prevalent problem, we implemented mid-quarter peer reviews, in which the students gave anonymous, typed feedback to each of their teammates in order to air any grievances they were experiencing on their teams, in order to allow students time to improve their relationships with their team members.

Course Improvements Piloted in Year 2 and their Effectiveness

This section addresses the three specific changes that were piloted in year 2 to address shortcomings of the course identified in year 1. The changes piloted were:

1) Grading: Weekly Teaching Assistant (TA) feedback
2) Creativity: Living notebooks and interactive lectures
3) Team Dynamics: Mid-quarter peer reviews

Using formative assessment, the effectiveness of these changes are discussed, as well as further improvements that will be implemented to increase the effectiveness of these changes.

Weekly TA Feedback

As mentioned previously, a weekly feedback form was designed to give teams regular feedback on their performance. This form was inspired by the numerous references to the importance of feedback in the literature on rubric design, and incorporated several important features cited in the literature (Andrade, 2005; Mertler, 2001; Trevisan et al., 1999; Sadler, 1989). The content of the feedback form is given in Appendix C. To study the effects of the feedback form on student performance, the form was administered to 5 of 9 teams (only those teams who were working on industry projects were considered for this portion of the study) in order to compare the performance between those teams who received weekly feedback, and those who did not. Amongst these 9 teams, those teams who received weekly feedback were chosen randomly. At the end of the quarter, the students gave a final presentation on their projects. The rubric used to grade the presentation, discussed previously, is provided in Appendix B. The students were assigned a grade by the instructor ranging from 1-5 (5 being the highest score) in five categories: 1) defining and understanding the problem, 2) identifying potential solutions, 3) evaluating candidate solutions, 4) planning, and 5) communication. The average scores of teams who received weekly feedback from the TAs are compared with the average scores of teams who did not received weekly feedback from the TAs, shown in Table 3. The difference in scores between teams that did and did not receive weekly feedback was at most 1.35. Overall, teams who received weekly feedback from TAs scored higher in all categories in comparison with teams who did not receive weekly feedback from TAs.

Table 3. Average final presentation scores for 5 industry teams who received weekly TA feedback forms compared with 4 industry teams who did not receive weekly TA feedback forms

Grading Category	Received TA feedback	Did not receive TA feedback
Defining the problem	4.2	3.5
Identifying solutions	4.2	3.75
Evaluating solutions	4.6	3.25
Planning	4.4	4.25
Communication	4.6	3.75

In order to explore this further, students were surveyed on how the weekly feedback from the TAs influenced progress on their project during the quarter. As seen in Table 4, the majority of students who received weekly feedback (65%) felt there was at least some improvement to their progress on their project due to the TA weekly feedback, though for most this was only slight.

Table 4. Influence of weekly teaching assistant feedback on progress of students' projects during year 2

Response	Response rate
Greatly improved	10%
Slightly improved	55%
Had no effect	24%
Slightly hindered	5%
Greatly hindered	7%

Student comments on the survey and focus groups indicated that students appreciated the TA feedback, but felt that it was too harsh at times. Additionally, the students indicated in the focus groups that TAs sometimes gave different feedback on the forms than that of the verbal feedback given by advisors during the meeting, which was confusing for the students. With regards to the categories in which students received feedback, students felt that the team's progress on their projects was the most helpful section to receive feedback on. As such, in the weekly feedback form for the second quarter of year 2, the other categories were removed. Students in the focus groups also felt that the ratings of Excellent, Good, Fair, and Poor were not as helpful as the TA's comments; therefore, these ratings were removed in the revision of the feedback forms.

Since the students indicated in the focus groups that TAs sometimes gave different feedback on the forms than that of the verbal feedback given by advisors during the meeting, the TAs were instructed to engage in a short debriefing meeting after the weekly meeting with the advisor to agree upon the feedback that is given to the students in the second quarter of year 2. Additionally, to further aid the students in tracking their progress in the capstone course, the new version of the TA weekly feedback incorporates the course weekly milestones (see Appendix A) by helping teams identify specific goals to achieve each week based on the milestones, or to come up with customized goals for each team's specific project if the milestones are not relevant for a particular project one week. This will help students track their progress on their projects during the quarter on a regular basis. The revised TA weekly feedback form implementing these changes is provided in Appendix D.

Creativity: Living notebooks and Interactive lectures

As mentioned previously, the formal reports of the fall quarter in year 1 were replaced with Living Notebooks in the fall quarter of year 2. The Living Notebooks were online digital notebooks in the form of a Google Drive or MS OneNote Notebook that all students on the team had access to, where team members shared data and files and tracked progress on their project.

As seen in Table 5, most students (81%) felt that the Living Notebooks resulted in at least some improvement on their project progress during the quarter. Encouragingly, none of the students felt that the Living Notebooks hindered their progress on their projects during the quarter.

Student comments in the focus groups and survey indicated that students like using the Living Notebooks, and appreciate that no specific format is required for the notebooks. Some students mentioned that they did not use the Living Notebooks as extensively as others, which could explain why they did not find the Living Notebooks as useful as other teams did. Additionally, several students expressed immense gratitude both in the survey and focus groups that they were no longer required to submit time-consuming formal reports in the fall quarter of the capstone class. The ME faculty did not notice any change in the quality of the team's projects this year as a result of the lack of multiple formal reports during the fall quarter in year 2.

Table 5. Influence of living notebook on progress of students' projects during year 2

Response	Response rate
Greatly improved	25%
Slightly improved	46%
Had no effect	25%
Slightly hindered	0%
Greatly hindered	0%
N/A: Team did not keep a living notebook	4%

Students in year 2 were surveyed on features of the capstone course that discouraged their personal creativity, as shown in Table 6. Between year 1 and year 2, the percentage of students who felt that the assignments were discouraging of their personal creativity was more than halved, as a result of abolishing the formal reports in the fall quarter of the capstone course.

Table 6. Course features that discouraged the personal creativity of students

Course feature	Response rate (year 1)	Response rate (year 2)
Assignments	46%	21%
Available resources	19%	4%
Fellow group members	16%	7%
Grading	14%	24%
Instructors	0%	0%
Project advisor	16%	6%
Structure	5%	7%
Other	0%	1%
No feature	38%	56%

Students in years 1 and 2 were also surveyed on features of the capstone course that encouraged their personal creativity, as shown in Table 7. The percentage of students who felt that the structure of the class encouraged their personal creativity more than doubled from year 1 to year 2. According to student feedback in the focus groups, this change may be attributed to the course lectures, which were revitalized in year 2 to be presented as interactive workshops, which the students greatly enjoyed. For the weekly lecture topics, see Appendix A.

Table 7. Course features that encouraged the personal creativity of students

Course feature	Response rate (year 1)	Response rate (year 2)
Assignments	19%	10%
Available resources	38%	38%
Fellow group members	68%	66%
Grading	8%	24%
Instructors	35%	44%
Project advisor	59%	62%
Structure	24%	53%
Other	5%	10%
No feature	3%	1%

Mid-quarter Peer Reviews

The students were expected to fill out a peer review in the middle of the academic quarter, in order to provide feedback to their team members so that any team issues could be resolved for the latter half of the quarter. Students were surveyed on the influence of the mid-quarter peer reviews on their ream dynamics, and the survey results are shown in Table 8.

Table 8. Influence of mid-quarter peer reviews on progress of students' projects during year 2

Response	Response rate
Greatly improved	4%
Slightly improved	29%
Had no effect	59%
Slightly hindered	4%
Greatly hindered	0%
N/A: Team did not fill out peer reviews	3%

Most students (59%) felt that the mid-quarter peer reviews had no effect on their team dynamics, although one-third of the students felt that the peer reviews at least slightly improved their team dynamics. Some students indicated in the survey and focus groups that they would have preferred to give feedback to their team members verbally, rather than on paper. Additionally, although the feedback was anonymous, students mentioned that it was very easy for them to guess which comments came from which of their team members, effectively nulling the anonymity of this method. Some students felt that the peer reviews were not useful because the teams had not been working together long enough to determine if any changes should be made in their fellow team member's behavior. Also, some students felt that their teams already worked very well together so there was no need to make any changes.

While most students in year 2 did not feel the peer reviews were beneficial during the first quarter, it will be useful to see if students find them more valuable in the second or third quarter of the capstone series. Repeating the peer reviews in a later quarter will give students more time with their team to determine whether there are any issues which need resolving, and students will provide feedback to their peers after working with them for a longer amount of time so they will have a better understanding of their team dynamics. Additionally, the students will be instructed to perform the reviews verbally under the supervision of the instructors. This will help students learn how to provide constructive criticism to their peers in person, which will also help them develop skills relating to behaving as professional engineers.

Assessment of Students' Achievement of ABET-guided Learning Outcomes

This study collected data via grading rubrics and student surveys to determine student achievement of four relevant ME departmental learning outcomes, which require that upon graduation, students:

1) can demonstrate the ability to design useful products, systems and processes (PSPs),
2) have experienced the use of current software in problem solving and design,
3) have an understanding of professional and ethical responsibilities,
4) and can work effectively on multidisciplinary teams.

Students in year 2 were surveyed before the course on their self-reported achievement of these four learning outcomes, to determine a baseline for the students' performance. They were then surveyed about their improvement on the learning outcomes at the end of the first quarter of the course. At the beginning of the course, the majority of students felt that they had acceptable performance in all four of the learning outcomes. After the course, the majority of students felt that they at least slightly improved in their abilities (see Appendix E for exact numbers) in all of the learning outcomes, as a result of the capstone course. The percentage of students who see improvement and the degree of improvement is expected to continue increase over the course of the academic year. This assessment is still underway, but preliminary findings related to the first two learning outcomes are discussed below.

Ability to design useful PSPs

The first of these learning outcomes is arguably the most important, and is also the most difficult to evaluate due to its open-ended nature. To collect direct evidence of the students' achievement of this learning outcome, as opposed to relying solely on student self-reporting of learning achievement, it was necessary to develop a grading rubric for students' final reports and final presentations. A literature survey revealed several important features of grading rubrics, including that they should:

- Test students on criteria they have been taught (Popam, 1997)
- Have specific criteria (Sadler, 1989)
- Directly relate to assessing learning outcomes (Trevisian et al., 1998)
- Have clear descriptions of what is needed to achieve a certain grade so students know what they are being assessed on (Tierny and Simon, 2004; Arter, 1993)
- Provide individualized feedback (Andrade, 2005)

These important features of grading rubrics were balanced with the need for ease of use so that engineering faculty, who are sometimes resistant to change, would be willing to make use of it. This led to a grading rubric that was specific, but also short, and easy to use. The most important features of a students' design project were identified from discussions with ME faculty, and this information was formalized and organized into the grading rubric in Appendix B. This grading rubric assessed the students' performance in five key categories that were directly related to the weekly milestones they were expected to complete throughout the quarter. This rubric allowed the course instructor to *directly* assess the students' abilities to design useful products, systems, and processes. As mentioned previously, this rubric was used by the course instructor to assess both the students' final presentations and final reports, and the students' final scores were tabulated from these rubrics. The grades assigned to each team by the instructor are given in Table 9.

Table 9. Final presentation and final report scores for all teams in year 2

Team	Presentation score (max 25)	Report score (max 25)
A	25	22.5
B	22	25
C	24	22.5
D	25	20
E	25	20
F	24	20
G	23	20
H	23	20
I	23	20
J	25	17.5
K	21	20
L	21	20
M	18	20
N	20	17.5
O	16	17.5
P	13	15

The student self reports on their perceived abilities to design PSPs at the beginning of year 2, and after one quarter of the design course are shown in Table 10. At the beginning of the quarter, 68% of students considered themselves to have an acceptable ability, and 76% of these students felt that they at least slightly improved in this ability by the end of the quarter. Of the very few students who felt that they had a poor ability at the beginning of the quarter, all students reported that they at least slightly improved in this ability.

Table 10. Students' self-reported abilities to design PSPs at the beginning of quarter (left column) and improvement at end of quarter (top row)

	Greatly improved	Slightly improved	No change	Worsened	Total
Very good	7%	14%	3%	0%	24%
Acceptable	19%	33%	16%	0%	68%
Poor	1%	5%	0%	0%	6%
N/A (did not use this ability)	0%	0%	2%	0%	2%
Total	27%	52%	21%	0%	100%

Use of software for problem solving and design

To address the second learning outcome, students were asked to provide information on the types of software they used for problem solving and design at the beginning of the course, and after one quarter. Typically, students used Solidworks, COMSOL, MATLAB, Abaqus, and Cambridge Engineering Selector in this capstone course. The software was provided to them at no charge by the university. The level of familiarity that students had with these various types of software varied from student to student, but most students had minimal experience with using these software for design at the beginning of year 2.

As seen in Table 11, of the 59 students who took both surveys, 57% of students reported using at least one new type of software for problem solving and 41% for design after one quarter, as compared to the beginning of the course. Most students learned to use one new type of software for both problem solving and design, although some reported up to 4 for problem solving and 3 for design. A breakdown of the percentage of students who used new types of software for both problem solving and design is shown in Table 11. This serves as direct evidence of the level of exposure that students gain to using software for problem solving and design as a result of the capstone course.

Table 11. Percentage of students who used 0-4 new types of software for problem solving and design in year 2

Number of new types of software	Problem solving	Design
0	43%	59%
1	42%	26%
2	7%	12%
3	5%	3%
4	3%	0%

The student self reports on their perceived abilities to use software for problem solving and design at the beginning of year 2, and after one quarter of the design course are shown in Tables 12 and 13. In both cases, about one-third of students fall into the category of initially rating themselves with an acceptable ability at the beginning of the quarter, then feeling that they slightly improved on this ability by the end of the quarter. While about a quarter of students felt that they started with an acceptable ability and experienced no change in this ability by the end of the quarter, this data is part of an ongoing study and we anticipate that the percentage of students who have experienced a change in their abilities may be quite different at the end of the year-long course. Encouragingly, the majority of students of students felt that their ability to use software for problem solving (62%) and design (57%) at least slightly improved as a result of the capstone course.

Table 12. Students' self-reported abilities to use software for problem solving at the beginning of quarter (left column) and improvement at end of quarter (top row)

	Greatly improved	Slightly improved	No change	Worsened	Total
Very good	0%	13%	8%	0%	22%
Acceptable	12%	32%	25%	0%	68%
Poor	0%	3%	5%	0%	8%
N/A (did not use this ability)	2%	0%	0%	0%	2%
Total	14%	48%	38%	0%	100%

Table 13. Students' self-reported abilities to use software for design at the beginning of quarter (left column) and improvement at end of quarter (top row)

	Greatly improved	Slightly improved	No change	Worsened	Total
Very good	2%	12%	17%	0%	30%
Acceptable	2%	35%	22%	0%	58%
Poor	2%	2%	5%	0%	8%
N/A (did not use this ability)	2%	2%	0%	0%	3%
Total	7%	50%	43%	0%	100%

Student self-reports on their perceived learning of the remaining two learning outcomes is given in Appendix E. Regarding the ability to work on multidisciplinary teams and students' understanding of professional responsibilities as an ME, the trend mentioned previously continued in that approximately one-third of students considered themselves to have an acceptable ability at the beginning of the quarter, and rated their ability as slightly improved by the end of the quarter. However, the results for students' understanding of ethical responsibilities were much more spread out, which is reflective of students' feeling on this ability. Students reported in focus groups that they do not feel they receive and adequate education on ethics in engineering prior to the capstone course, and even during the capstone course they are somewhat exposed to this ability, but not to a great extent. As always with student self-reports, though, it is important to remember that a students' perceived ability may not accurately reflect that students' actual ability in a certain learning outcome, and direct evidence often provides a better measure of this ability.

Conclusion

In conclusion, this paper presented key improvements to a senior mechanical engineering design capstone course and determined the efficacy of the piloted improvements, with a focus on encouraging openness and creativity in the course, balanced with a clear structure. Specifically, this paper discussed 1) lack of feedback in the capstone course, which was addressed by a weekly feedback form, 2) the inclusion of too many formal assignments, which was addressed by introducing a living notebook, and 3) issues with working on teams, which was addressed by a mid-quarter peer review. Our study shows that the introduction of weekly feedback forms had evident impact on the students' grades on their final presentations, and that the students appreciated the targeted comments from the TAs provided on the feedback forms. We revised our weekly feedback form for future use, taking the student comments into account. The living notebooks and interactive lectures helped to structure the class in a way that encouraged the students' creativity in the open-ended design course. Students were also supported with peer reviews to give them the ability to provide each other with feedback on their team's performance. These course features were balanced by the rubric designed to directly assess students' design abilities, as it provided some structure to directly quantify this open-ended ability. A method of directly assessing students' use of software was also discussed, as well as their self-reported abilities in four learning outcomes. This study outlines key methods to balance openness and creativity in a capstone design course with a course structure that provides students with the support they need to develop into engineers.

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Appendices

Appendix A. Weekly milestones and lecture topics in the first quarter of year 2

Week	Milestone
W1	Milestone: Decide on project and project teams Lecture: Project Introduction
W2	Milestone: Team's living notebook created: first draft of needs, engineering characteristics, team goals Lecture: Course Overview (grading, organization, etc.)
W3	Milestone: Gathering information, research, patent searches, understanding of the basic technology Lecture: Overview of Project Resources
W4	Milestone: Redraft of needs, engineering characteristics, more research, notes from customers Lecture: Revising Thoughts and Learning to Sketch I
W5	Milestone: Generate concept list and whittle to identified concepts for concept sketch or benchtop analysis Lecture: Generating Concepts and Learning to Sketch II
W6	Milestone: Develop experimental plan for experiments and/or concept sketches, begin purchasing supplies, examining campus resources, etc. Lecture: Planning Experiments
W7	Milestone: Build and run experiments Lecture: Leveraging Photography and Videography for the documentation of engineering products workshop
W8	Milestone: Conclude all experiments and builds, collect and record data Lecture: Effective presentations workshop
W9	*Thanksgiving break* Lecture: Professionalism in Technical Writing workshop
W10	Milestone: Final Presentations

Appendix B. Grading rubric for final presentations and reports

Criteria *Qualities outlined in this column describe an "Excellent" team*	Rating				
Defining and understanding the problem: Team has a clear and insightful understanding of the problem with consideration of relevant contextual factors (e.g., customer's requirements, other patents/products, resources, etc.)	Excellent	Very good	Good	Fair	Poor
Identifying potential solutions: Team has proposed reasonable, well thought out solutions for solving the problem within the established context (e.g., customer's requirements, other patents/products, resources, etc.)	Excellent	Very good	Good	Fair	Poor
Evaluating candidate solutions: Team has completed insightful and thorough evaluation (e.g., modeling, testing, prototyping, etc.) of candidate solutions	Excellent	Very good	Good	Fair	Poor
Planning: Team has identified a candidate design (or a few) to pursue and has a solid plan for completing the work ahead	Excellent	Very good	Good	Fair	Poor
Communication: Team communicates all of the above in a clear and effective manner	Excellent	Very good	Good	Fair	Poor

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Appendix C. Weekly TA Feedback Form

1. Given the stage of the design process that the team is currently in, how would you rate quality of the team's work? Please consider the following in rating this criteria:
   - Are the students making thoughtful, informed design decisions?
   - Are the students producing work that is technically accurate?
   - Are the students thinking critically about their design problems?
   - o Excellent; no improvement needed, quality of work is completely satisfactory
   - o Good; could be improved, but quality of work is mostly satisfactory
   - o Fair; needs improvement, quality of work is somewhat dissatisfactory
   - o Poor: needs significant improvement, quality of work is completely dissatisfactory

Please indicate below what the team needs to do to improve their rating and what the team did well:

2. Given the stage of the design process that the team is currently in, how would you rate the team's progress? Please consider the following in rating this criteria:
   - Are the students making timely progress on their project?
   - Are students completing an appropriate number of the tasks assigned to them each week?
   - o Excellent; no improvement needed, team is on schedule
   - o Good; could be improved, but team is mostly on schedule
   - o Fair; needs improvement, team is behind schedule
   - o Poor: needs significant improvement, team is extremely behind schedule

Please indicate below what the team needs to do to improve their rating and what the team did well:

3. Given the stage of the design process that the team is currently in, how would you rate the presentation quality of the team's work? Please consider the following in rating this criteria:
   - Is the presentation organized?
   - Is the presentation clearly thought out?
   - Does the presentation have clear figures?
   - Does the presentation contain an appropriate level of detail?
   - Does the presentation appear to be carefully rather than hastily put together?
   - o Excellent; no improvement needed, presentation quality is completely satisfactory
   - o Good; could be improved, but presentation quality is mostly satisfactory
   - o Fair; needs improvement, presentation quality is somewhat dissatisfactory
   - o Poor: needs significant improvement, presentation quality is completely dissatisfactory

Please indicate below what the team needs to do to improve their rating and what the team did well:

4. Given the stage of the design process that the team is currently in, how would you rate the team's professionalism? Please consider the following in rating this criteria:
   - Are the students on time for their advisor meeting?
   - Do the students demonstrate that they value the advisor's time and take the advisor meeting seriously?
   - Do students consider the larger impact or ethical concerns of their efforts (addressing safety of the team, the customer, the environment, etc.)?
   - Do students exhibit self-regulation and honesty?
   - o Excellent; no improvement needed, team is highly professional
   - o Good; could be improved, but team is mostly professional
   - o Fair; needs improvement, team is somewhat unprofessional
   - o Poor: needs significant improvement, team is extremely unprofessional

Please indicate below what the team needs to do to improve their rating and what the team did well:

5. Given the stage of the design process that the team is currently in, how would you rate the group's effectiveness as a team? Please consider the following in rating this criteria:
   - Is each student is making meaningful contributions to the progress of the project, rather than a subset of the team doing the majority of the work?
   - Do the students engage in collaborative rather than combative interactions?

- o Excellent; no improvement needed, team is highly effective
- o Good; could be improved, but team is generally effective
- o Fair; needs improvement, team is somewhat ineffective
- o Poor: needs significant improvement, team is extremely ineffective

Please indicate below what the team needs to do to improve their rating and what the team did well:

Appendix D. Revised Weekly TA Feedback Form

1. Given the goals identified by the team last week, is the team is making adequate progress on their project (choose one option below)? If not, please identify key steps the team should take to get back on schedule.

- o Team is making adequate progress.
- o Team is not making adequate progress.

Steps to get back on schedule:

2. Please identify, in bullet form, the goals of the project team for the following week, as agreed upon by the advisor, TA, and project team, based on the weekly milestones (or the team's specific project if the milestones do not apply).

3. Please provide any additional praise and/or constructive criticism you may have for the project team (e.g., quality of team's presentations, quality of team's work, effectiveness as a team, etc.).

Appendix E.

Table 14. Students' self-reported abilities to work on multidisciplinary teams at the beginning of quarter (left column) and improvement at end of quarter (top row)

	Greatly improved	Slightly improved	No change	Worsened	Total
Very good	7%	8%	8%	0%	23%
Acceptable	12%	27%	15%	0%	53%
Poor	0%	2%	3%	0%	5%
N/A (did not use this ability)	3%	5%	10%	0%	18%
Total	22%	42%	37%	0%	100%

Table 15. Students' self-reported understanding of professionalism at the beginning of quarter (left column) and improvement at end of quarter (top row)

	Greatly improved	Slightly improved	No change	Worsened	Total
Very good	12%	13%	10%	0%	35%
Acceptable	15%	32%	12%	0%	58%
Poor	0%	2%	0%	0%	2%
N/A (did not use this ability)	5%	0%	0%	0%	5%
Total	32%	47%	22%	0%	100%

Table 16. Students' self-reported understanding of ethics at the beginning of quarter (left column) and improvement at end of quarter (top row)

	Greatly improved	Slightly improved	No change	Worsened	Total
Very good	10%	17%	13%	0%	33%
Acceptable	3%	17%	13%	0%	33%
Poor	0%	3%	2%	0%	5%
N/A (did not use this ability)	5%	13%	3%	0%	22%
Total	18%	50%	32%	0%	100%

Small and Short Range Radar System Open Source Developments for a University RF/Microwave Systems Laboratory Class

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Abstract
Gregory Charvat and his collaborators at MIT Lincoln Labs pioneered a "Small and Short Range Radar System" do-it-yourself construction project[1]. MIT has put together a one week short course based on this design and distributed an open courseware set of documentation for this radar. The open courseware documentation has created a community of experimenters and students that have spawned variants of the original design. The current design variants cost about $750 to build since the designs use a Voltage Controlled Oscillators (VCO), amplifiers, frequency mixers, and power splitters with SMA connectors. This paper addresses how to turn the "Small and Short Range Radar System" into an inexpensive, higher performance, and compelling project-based-learning university laboratory course for Electrical and Computer Engineers. The new project variant discussed in this work can be built for less than $100 and can be incorporated into a compelling RF/Microwave laboratory or systems engineering project course over the duration of an academic quarter or semester.

Introduction
The first key innovation was to move away from expensive components with connectors towards the use of surface mount components. The key innovation used in the class is construction of prototype sections of the radar system using semi-rigid coaxial cable interconnections between surface mount parts. This allows for rapid prototyping and individual component testing prior to system assembly. The second key innovation was to use phase locked loop (PLL) designs to construct frequency-sweeping local oscillators with superior spectral purity (phase noise). PLL designs simplify system assembly and enable higher performance for both the Frequency Modulation Continuous Wave (FMCW) and the Doppler modes of operation.

This new "Small and Short Range Radar System" variant has been used as the basis of an RF/Microwave projects laboratory elective for the last two years. Students start by reviewing the MIT Open Courseware materials and the previous year's design reports. The next meeting has student teams target improvements that form the basis for their project development. The project design and construction proceeds over the quarter leading to final project demonstrations. Industry partners familiar with radar systems have provided mid and end-of-project feedback along with financial support for the laboratory project. Students quickly get immersed in the excitement of building a complete radar system with software that can make real measurements around the campus environment.

Description of Home-Brew Radar System Operation
The block diagram of the Gregory Charvat small and short range do-it-yourself construction project[2] is shown in Figure 1.

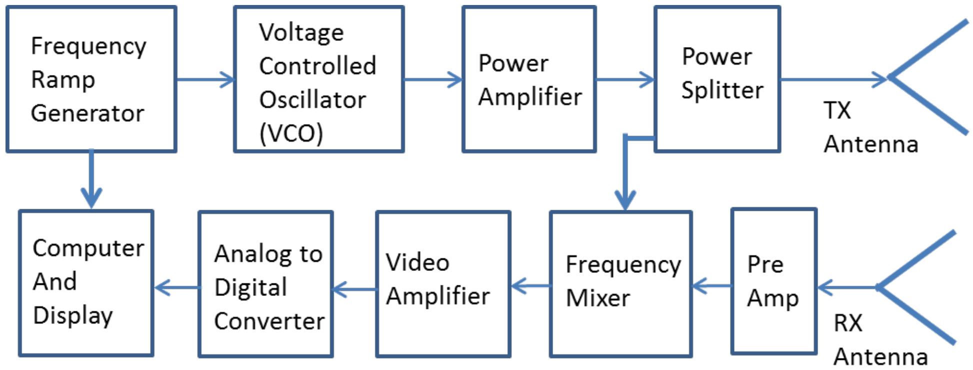

Figure 1: This is the block diagram of an experimental radar system developed by Gregory Charvat and outlined in his textbook "Small and Short-Ranged Radar Systems[1]." The radar system can operate in two modes: FMCW and Doppler. The FMCW mode sweeps the RF output frequency in a saw tooth waveform, while Doppler mode utilizes a single frequency.

Frequency Modulated Continuous Wave (FMCW): The frequency ramp generator repetitively tunes the VCO in a linear ramp versus time. The signal power is boosted by a power amplifier which is then radiated by the transmit (TX) antenna. The radiated signal propagates to a test object and then reflects back to the receive (RX) antenna with a time delay. The received signal is frequency mixed against a split-off version of the TX signal. The output of the frequency mixer produces a difference frequency proportional to the round trip duration of the signal to the measured object. The difference frequency signal is then amplified and applied to an analog to digital converter (ADC) and computer for final display processing.

Doppler: The ramp generator is set to a constant voltage producing a single stable frequency from the VCO. The signal from the TX antenna propagates to the test object. If the test object is moving away from the radar system, the reflected signal frequency will be reduced at the RX antenna due to Doppler shift. The frequency mixer output is equivalent to the Doppler shift frequency. The video amplifier applies the signal to the ADC and computer/display.

The radar system was designed to work in the unlicensed 2.4 GHz band. The output power from the TX antenna was below 100mW. The cost of this radar system is dominated by the cost of the high frequency amplifiers, mixers, splitters and voltage controlled oscillators. A company called Mini-Circuits (www.minicircuits.com) is a common vendor for these parts. While an amplifier with an SMA connector for this frequency range costs about $80, a surface mount amplifier component can be purchased for less than $3 from the same vendor. Thus a surface mount component strategy was used to reduce the cost of the project with the trade-off of more time consuming (and perhaps more educational) build processes.

Project Innovations to Adapt this Project into a Graduate Laboratory Course

The key issues adapting this small radar system project into a University technical elective laboratory class are as follows:

a. The project costs need to be reduced for student affordability
b. Building individual surface mount components requires improved skill in assembly, testing, and troubleshooting
c. The course must be accomplished in an eleven week quarter. Semester based course could have a more ambitious set of project goals.

The major component of cost reduction in this project is due to the use of inexpensive surface mount components, semi-rigid coax cables with SMA connectors, and dead-bug construction techniques. Figures 2 through 5 show examples of this type of construction.

Dead-Bug Construction Technique using Semi-Rigid Coax & Surface Mount Components

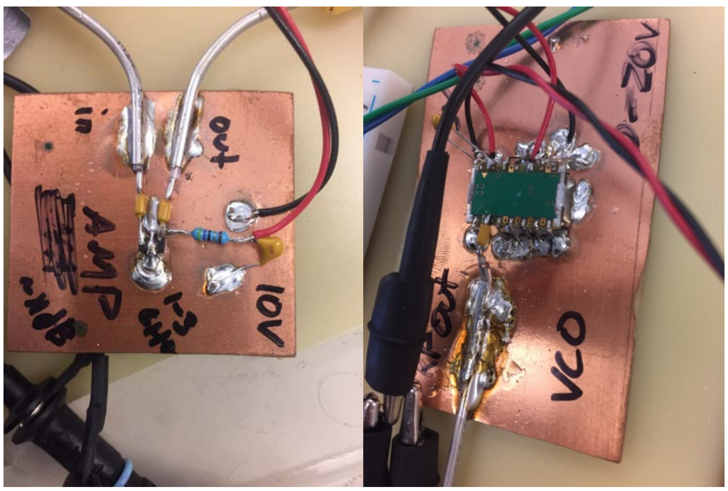

Figure 2: Dead-Bug construction of the power amplifier (left) and voltage controlled oscillator (Right). In dead-bug construction, the surface mount components are soldered upside down on a double-sided copper-clad PC board. 0.085 inch semi-rigid coax assemblies with SMA connectors on one end are constructed on the first day of class. The semi-rigid coax assembly end is soldered adjacent to the desired pin of the surface mount component. Care is made to minimize the lead length of connections to the components to improve high frequency performance. Students learn a lot about proper soldering techniques. The soldering quality on the left picture is adequate. The soldering quality on the right shows learning opportunities. This construction technique has worked well for the authors for frequencies approaching 10 GHz.

Figure 3: The picture on the left shows a three-resistor power splitter along with the three 0.085 inch semi-rigid cable assemblies constructed by the class. The figure on the right shows a close in photo of the three-resistor splitter. The three resistors are each 16.66 ohms giving each port a 50 Ohm impedance and 6 dB nominal signal loss. This assembly project is challenging for the students and requires proficiency in handling and soldering small parts. The center conductor lead length is minimized so that the inductance does not limit the frequency performance of the splitter. The students learn the importance of circuit miniaturization as a result of building these components.

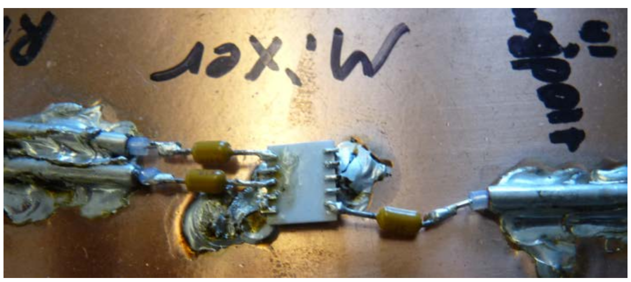

Figure 4: This figure shows a surface-mount mixer connected to the 0.085 inch semi-rigid coaxial assemblies. The surface mount mixer has several pins that are grounded to the PC board in order to hold the mixer solidly in place. Next the semi-rigid coax is put into place. Finally, the radial lead capacitors are used to interconnect the coax to the mixer. The solder quality on the right is adequate, while the left side is marginal.

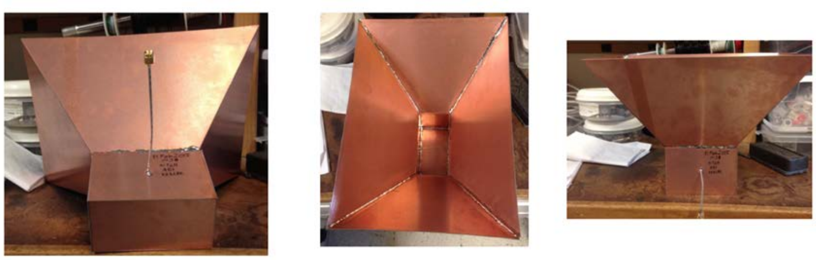

Figure 5: The most cost effective solution is found in the original work by Sharvat[2] that uses coffee-can circular waveguide antennas, while students are encouraged to try a range of different antenna options to improve performance. This particular group chose to construct a horn antenna out of double-sided PC board material. 0.085 inch semi-rigid coax assemblies are

constructed and soldered into place a quarter wavelength away from the waveguide back-short. Students have also tried Yagi-Uda, Quagi, and Helical antennas.

System Construction and Characterization of the Radar System

Once all of the individual high frequency components are constructed and tested individually, it is time to assemble the entire radar system. Figure 6 shows an example layout of the radar system interconnection.

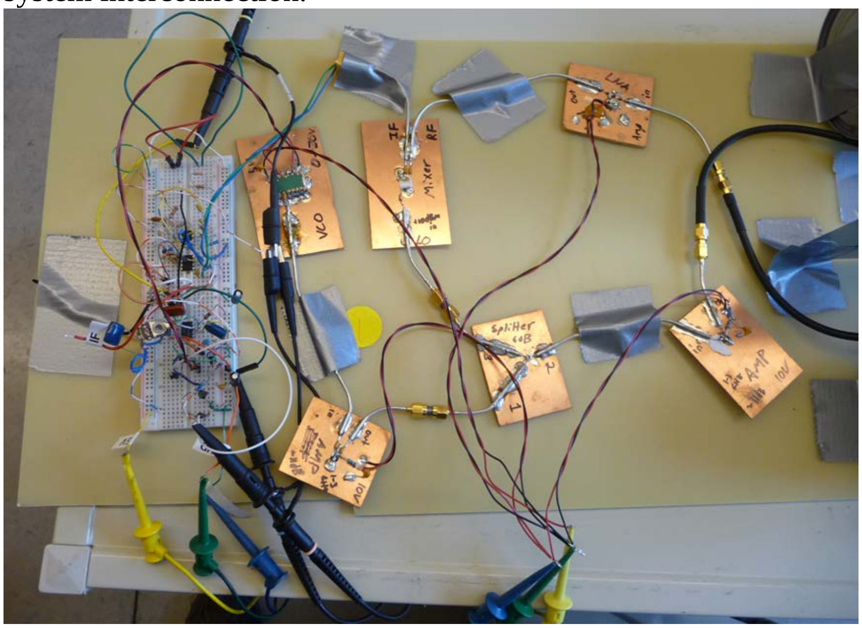

Figure 6: The radar system is assembled and system troubleshooting begins. The low frequency IF processing chain was constructed on the white breadboard on the left. Commercial DC power supplies were used at this stage of testing.

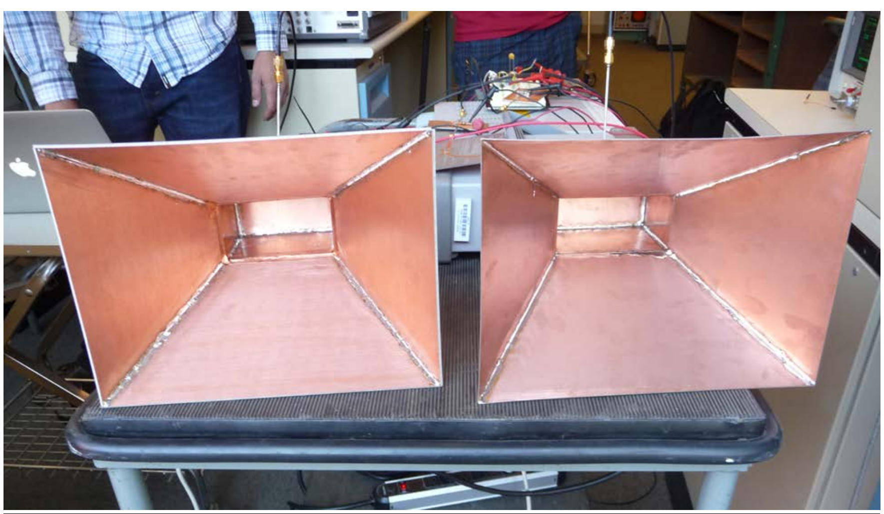

Figure 7: A separate TX antenna and RX antenna are used since circulators are expensive. This antenna system is more complicated to build than the coffee can antennas that are used in the original Charvat system.

Figure 8: Pictured is a completed system undergoing outdoor testing. The students in this case were experimenting with placing a copper sheet between the TX and RX antennas to decrease cross-coupling.

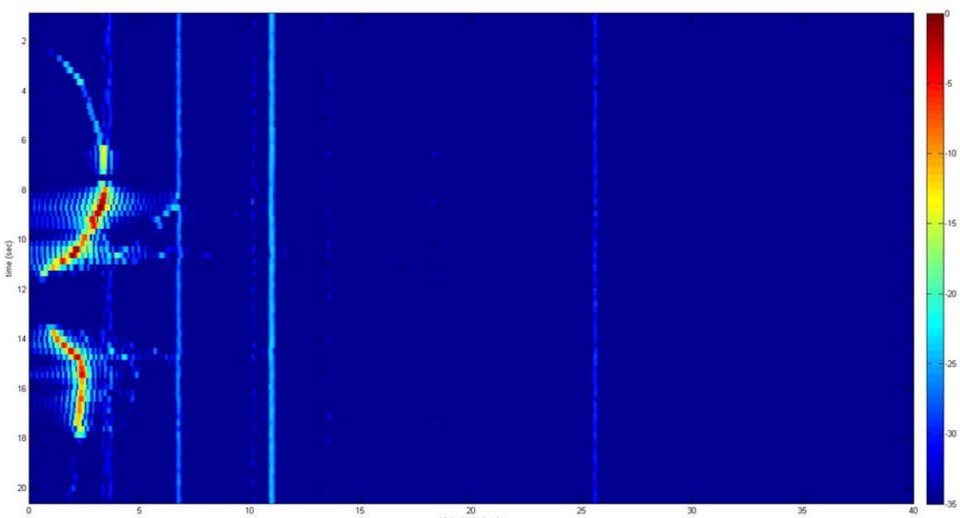

Figure 13: The Doppler mode output of the radar post processing. The horizontal axis is velocity, the vertical axis is time. In this case the student was running towards and away from the radar antennas repeatedly. The software package for this radar signal processing is available from the MIT Open Courseware.

A detailed video outlining system level testing of this radar system can be found on YouTube[3].

Work In Progress in WinterQuarter 2016

Students in Winter Quarter 2016 are constructing new revisions of this design. The goal of the project each year is to learn from the previous year's groups and identify areas for improvement. Final reports and presentations are available from the previous year's activities. Key goals of this new 2016 revision are:

1. The local oscillator is phase locked to a crystal reference oscillator. This phase locked loop (PLL) approach is intended to improve the phase noise performance of the microwave oscillator and to linearize the sweep. New PLL integrated circuits from Texas Instruments are now available since FMCW radar systems are becoming important for automotive applications. The oscillator will be phase locked during the entire sweep due to the fractional-N synthesis features of the PLL integrated circuits. Good phase noise performance is especially important for the Doppler radar mode.
2. Students in this year's class are developing all of their high frequency components on a custom surface mount board. RF test points are placed around the board so that individual components can be tested without any soldering required.
3. Students are trying to replace the laptop computer used for signal processing with a Raspberry Pi.

Summary

This paper outlines an evolutionary path for the Charvat do-it-yourself small and short range radar system adapted to a University laboratory class. The cost of the design has been reduced so that it becomes affordable for a University setting and a team of eager student experimenters. Students improve soldering skills due to the handling of small components in a dead-bug circuit configuration. The students also become exposed to the versatility of semi-rigid coaxial cable segments as a quick and easy building tool for dead-bug. The students learn a wide range of electronics project skills: RF electronics, low frequency analog design, and digital signal processing techniques. The students improve techniques for system troubleshooting. Currently work in progress includes advanced PLL design, custom surface mount boards, and low cost portable computing platforms.

References

[1] Gregory L. Charvat, "Small and Short-Range Radar Systems", CRC Press (2014), ISBN 978-1-4398-6599-6
[2] G. L. Charvat, A. J. Fenn, and B. T. Perry "The MIT IAP radar course: build a small radar system capable of sensing range, Doppler and synthetic aperture radar (SAR) imaging" Atlanta, GA: IEEE Radar Conference, May 2012.
[3] Michael Harriman, Adi Singani, Bradley Hutchinson, and Errol Leon "FMCW Radar" https://www.youtube.com/watch?v=qAElFs3oYA4

Note From Raytheon Authors: This document does not contain technology or technical data controlled under either the U.S. International Traffic in Arms Regulations or the U.S. Export Administration Regulations.

Sin el agua no hay vida: Providing Under-Represented Engineering Undergraduates Opportunities for Real-Time Learning for Student Persistence and Retention

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Abstract
Providing engineering undergraduates opportunities to apply their classroom-based learning into real-world situations enhances their understanding of the disciplines they will soon practice, but also contributes to a multi-stakeholder perspective that highlights the human side of engineering. The authors, along with colleagues in the College of Engineering and Science, designed a multi-disciplinary senior design project that incorporated classroom and field-based experiences in an international setting. This project provides participating students the ability to attend to global challenges such as water scarcity, renewable energy, food security, and public health, but also opportunities to partner with government officials, university faculty, professional engineers, and civil society. As Russell, Hancock, and McCullough have argued, undergraduate participation in hands-on research is "widely believed to encourage students to pursue advanced degrees and careers in science, technology, engineering, and mathematic fields," (2007, 548). A 2003 report by Treverton,and Bikson concluded that "to effectively exercise leadership in the global workplace, employees must demonstrate…a multidimensional and well-integrated repertoire of skills that include professional or technical knowledge related to the organization's core business; managerial ability that includes effective interpersonal and teamwork skills; a strategic understanding of their organization and industry in a global context; and…cross-cultural experience," (2003). International engineering research and design experiences applied to a real world problem encourages and enhances the skill-building necessary for twenty-first century engineering employment. The goal of the project was simple, to take undergraduate students from the United States to Latin America for the expressed purpose of exposing them to cultural and practical experiences they could not have on their own campuses. Over three years (2011-2014), students traveled to Latin America and consulted with community members, interviewed professional engineers, and designed a complementary water distribution system for a small rural community in Ecuador that was sustainable and environmentally and socially sound. They used these experiences as the basis for their senior design projects, capitalizing on the experiences they had to bring depth and real-world applicability to their work. For those students who had the international experience (not all could travel, so some participated only in campus-based activities), they stated that it changed the way they "saw" engineering. It fostered a belief in engineering as a "helping" discipline. Projects like *Sin el agua no hay vida* afford engineering students opportunities to work in multidisciplinary teams, experience engineering in practice, and expose them to current day global challenges.

Introduction

Engineering faces several challenges in the twenty-first century. The first reflects a need in the United States for more engineering degrees to be awarded in order to continue to thrive in the global market. The second is to increase diversity in engineering among historically underrepresented populations: African Americans, Hispanics, and Women. Using two case studies, one from the Stevens Institute of Technology and the second from the California State University Office of the Chancellor, this paper describes an attempt to engage students both in the lower division and upper division sectors of their undergraduate education, in order to provide maximum opportunity for engagement and success.

Significance

The President's Council of Advisors on Science and Technology (PCAST) published in 2012 "Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics." This report provided "a strategy for improving STEM education during the first two years of college that…is responsive to both the challenges and the opportunities that this crucial stage in the STEM education pathway presents," (2012). They (the PCAST team) found that despite strong efforts, "fewer than 40% of students who enter college intending to major in a STEM field complete a STEM degree," (2012). Reasons given by students as to why they chose to migrate out of STEM included:

- Uninspiring introductory "gateway" courses
- Difficulties in passing critical Math courses with little support from their institutions
- An unwelcome environment from faculty

To address this "leak" in the STEM pipeline, educators were being called upon to find solutions; using high impact practices, redesign of introductory courses, and professional development for faculty. This paper, results from efforts to supplement the Senior Design program at Stevens Institute of Technology and increase persistence and close the achievement gaps in the California State University system, hopes to share best practices with respect to engineering education; by revealing how high impact practices can and do make a difference in a students' experiences in higher education and work to increase diversity in engineering. The authors believe that engaging engineering undergraduate students in real-world challenges, affords them opportunities to learn what it is to "be" an engineer, to learn how engineering and civil society interact, and exposes them to design problems they will face once they graduate. In addition, by engaging students and faculty from multiple disciplines around a central research theme (sustainability), fostering collaborations across departments, divisions, and geographic space, we model activities and behaviors reflective of life after the university.

Discussion

As Aglan and Ali argued in their 1996 article "Hands On Experiences: An Integral Part of Engineering Curriculum Reform," engineers in the future "will be faced with problems that require multidisciplinary solutions." (Aglan and Ali, 1996). Similarly, Carlson and Sullivan highlighted the Integrated Teaching and Learning Program at the University of Colorado, a program that "reflected the real world of engineering" with "active learning and project based design and problem solving experiences." (Carlson and Sullivan, 1999). National literature has shown that engagement in hands on activities improves engineering student retention (Knight et.

al., 2007; Carlson and Sullivan, 1999; Coyle et. al., 2005) in instances where community involvement occurs, learning benefits both the community and the student (Coyle et. al., 2006). Like Purdue, the goal at Stevens was to transform the experiences of students. The project was designed to ensure that when they left Stevens, they had both the technical skills necessary as young engineers and the professional skills to succeed. Providing these students with opportunities to work in a team environment, communicate in an effective way to engineers and others, learn how to balance customer demands and budgetary and time deadlines, and build an awareness of ethical, social, legal, and environmental issues that may arise during a project's lifespan were all experiences that were enhanced through participation (Coyle et. al, 2006).

Why Sustainability?

The Center for Sustainable Engineering, a collaborative between the University of Texas at Austin, Carnegie Mellon University, and Arizona State University, "benchmarked the extent to which sustainability concepts are being incorporated into the research and educational missions of colleges of engineering in the United States," (Murphy et.al., 2009). This was largely due to a movement five years earlier to assess the integration of sustainability into engineering programs due to societal attention for the subject and new avenues for funding. With research funding for sustainable engineering at an all-time high, with roughly a quarter of a billion dollars in funding (Murphy et. al., 2009), and the public's interest in "all things green," it is clear that sustainability and sustainable engineering provide unique opportunities to integrate social dimensions with technical training through engineering education. Another reason for using sustainability as a theme for engineering research and design is that it "greatly increases the spatial, temporal, biological, and intellectual scale on which engineering criteria must be based," (Lemkowicz et. al., 1996). Steinemann (2003).

Sustainability as a theme also provides ample opportunities for multi-disciplinary work. Given its status in the forefront of many discussions present in the political, economic, and social spheres, sustainability and sustainable development serve as platforms for investigation in a wide range of disciplinary projects. On March 29, 2015, President Barack Obama signed Executive Order 13693, "Planning for Federal Sustainability in the Next Decade" In this order, the goal was to maintain Federal leadership in sustainability and Greenhouse gas emission reductions. Federal agencies will "improve agency water use efficiency and management, including storm-water management." (Executive Order 13693, 80,057, 2015). For future engineers, the exposure to sustainability while in the university setting affords the understanding of its core principles, its challenges in the real-world, and its relevancy to the discipline from an employment perspective. Thus, in choosing sustainability as the overarching theme for this hands-on research, Digrius and Brunell believe it embeds current and future trends in engineering practices into the design program in meaningful ways.

Problem Based Learning- Engagement for Student Success

Problem-based learning promotes learning by doing. In many universities, such as Stevens Institute of Technology and campuses within the California State University system, incorporating real-world situations into the classroom or design activities reflect experiences students will face as professionals. What is positive about problem-based learning, or PBL, is that it allows students to work towards solutions to problems, as opposed to being told the solutions, developing critical skills necessary as engineering professionals (Steinemann, 2003). As Steinemann noted (2003), PBL emerged over three decades ago to "improve methods of professional instruction." Since problem solving is, as Singer et. al., described, the "quintessential expression of human thinking," incorporating opportunities for problem-solving, particularly on topics of global import, having engineering participate in such activities encourages their use (Singer, Nielson, and Schweingruber, 2012).

Diversity in Engineering

In the California State University System, among the 2011-2013 graduates in Engineering, the average number of units earned towards their degree was 155.62, the second highest total of all disciplines offered in the CSU. It took, on average, 5.01 years for those students to graduate. These freshman cohorts, who began in the CSU between 2005 and 2007, saw a 47% graduation rate among their peers overall. Looking at the demographic breakdowns of several of the CSU campuses that have engineering programs, CSU Dominguez Hills is 85% URM(Underrepresented Minority student), CSU Los Angeles is 75% URM, CSU Northridge is 60% URM, Fresno State is 52% URM (increased 21% over the past five years), and CSU Long Beach is 46% URM.

There is evidence that supports the notion that underrepresented minority students in engineering, particularly women, "are attracted to careers where they feel that they have a positive impact on society," (Mihelcic, 2003). Digrius and Brunell support the use of high impact practices to engage students, especially historically underrepresented students in the engineering fields. Learning communities have shown real value in student success; participation in a hands-on engineering project with peers constitutes a learning community. Since most learning communities "incorporate active and collaborative learning activities and promote involvement in complementary academic and social activities that extend beyond the classroom," (Zhao and Kuh, 2004) it is clear that by incorporating the types of experiences Digrius and Brunell have afforded senior design students can and should be considered for students in their first two years of an engineering degree.

Engagement increases a student's likelihood in persisting in a STEM field and graduating with a degree in a STEM field. Kinzie and Kezar's 2006 article, "Examining the Ways Institutions Create Student Engagement: The Role of Mission," focuses on varied approaches by 20 institutions to engage students in the early period of their academic careers in higher education. A quality education includes active learning and since "many Blacks, Hispanics, and Women have faced hurdles that have made it difficult for them to fully benefit from education," by actively engaging these students, but all of our students, through hands-on engineering opportunities, we can increase diversity in the engineering fields (Kinzie and Kezar, 2006). Turning back to the role of engagement in higher education, student engagement through active learning creates opportunities for students to "see themselves" as engineers, even before they have completed their engineering degree. Exposing students to real world problems and stakeholder needs allows them to apply their technical skills in a multifaceted way with real life implications.

Research

In 2010, Digrius was invited to serve as a consultant on the development of a new major at Drew University, funded by the National Aeronautics and Space Administration, Environmental Science and Sustainability by her colleague and former undergraduate advisor, Dr. Maria Masucci. Digrius had recently joined the faculty of Stevens Institute of Technology (Fall 2009) and was looking for a research program by which to integrate her students. While in Ecuador, staying in a small rural village on the coast, she encountered an ongoing debate between community members and the government focused on access to and use of water resources in the region. Given her background in environmental archaeology and human/environment interactions, she saw an opportunity to integrate her students into a real world challenge located on the Santa Elena Peninsula. Upon return to Stevens at the end of the Summer term, 2010, Digrius called upon Brunell to partner in this research and provide opportunities for students to work on integrated teams both on campus and in the field. In the fall of 2010, a call was placed for students interested in participating in this project, *Sin el agua no hay vida*. Selection was based upon a pre-determined criteria: students had to be an upper division student; students had to have some proficiency in Spanish; students had to have a 3.0 GPA or above; students had to be willing to live and work under "primitive" conditions. Four students were chosen for the first pilot, and during the summer of 2011, three civil engineering and one environmental engineering student accompanied Digrius to Ecuador. Two of these students were Hispanic; one was native Ecuadorian and the other Colombian. The students spent 30 days in the field—seven days in residence at the local Polytechnic University in Guayaquil (Escuela Superior Politécnica del Litoral-ESPOL) and twenty-one days in the village of El Azúcar. During the three weeks spent in the village, the students interviewed community members, engineers, faculty at the university, and governmental officials to ascertain the construction of the current water system and the politics surrounding its use. They mapped the existing and abandoned canal systems, in order to assess whether it would be better to fix the canal as it was designed or reconfigure the system in a more sustainable way. Finally, they learned more about how engineering is done in a developing nation, the challenges faced by lack of resources, and how a multi-stakeholder partnership operates.

When these students arrived back to Stevens in the Fall term of 2011, it was their goal to use the information and experiences they had in the field towards their Senior Design Project. The student team was expanded to include other students who had not been to the field, and worked to design a complementary water system that used solar energy instead of a diesel engine to pump water from the reservoir to the proposed canal and albarrada system. During that year, Drs. Digrius and Brunell saw the extent to which having that field experience shaped the students' work, attitudes, and understanding of the need for multidiscipline engineering to solve this global problem. They saw their work as contributing to the betterment of the quality of life for a group of individuals who needed their expertise and their skills to allow for their economic and social growth. All four of these initial students participating in the pilot are now employed by engineering firms in the United States and have been successful in translating their experiences in Ecuador to their current positions.

In 2012, a second group of senior engineering students were chosen to participate and continue with the project. This cohort was larger, there were eight undergraduates and one Ph.D. candidate in Environmental Engineering working with Digrius in the field. The range of disciplinary representation on this trip was also more diverse: civil, mechanical, electrical, and environmental engineering undergraduates along with two Chem/Bio (Pre-Med) students and a social science/history major. The goal for this trip was to map the abandoned water conveyance system from its source at the reservoir to the canal system (old and new) in order to determine the feasibility of re-opening the old canal (constructed in the 1960s) for access by the farmers residing alongside. The new canal, constructed between 1984 and 1998, was placed on the western edge of the reservoir, away from the poor rural farmers and closer to land held by large land speculators. The students, in addition to mapping all water conveyance structures in the area, met with CEDEGE (la *Comisión de Estudios para el Desarollo de la Cuenca del Rio Guayas*) engineers that had worked on the reconstruction of the system to assess its current usage and future access. They met with and interviewed community members (poor rural farmers) who benefitted economically and socially from their re-access to water from the reservoir. With assistance from engineering faculty Dr. Marco Pazmiño, then Director of the Renewable Energy Laboratory (Lab FREE) at ESPOL, the students investigated renewable and alternative energy sources to fuel the pumps needed to pull water from the reservoir into retention basins, then into their fields.

Reflecting back on the academic and professional trajectories of the students who participated in the *Sin el agua no hay vida project*, between 2011 and 2013, most have gone on to positions in engineering firms. J. R., one of the original students in the 2011 pilot, currently serves as Assistant Engineer for Hazen and Sawyer, a position he obtained because of his participation in this international project. M.H., another of the students participating in the pilot 2011 season, works for Louis Berger International as Project Coordinator in Abu Dhabi. C.L., a student who participated in the 2013 season, now works for LANDTECH Consultants, Inc. as Associate Civil Engineer. F.C., another member of the 2013 season, works for POWER Engineers as an Electrical Engineer. H.G., also from the 2013 season, is currently employed as a Quality Engineer at Case Medical, Inc. Participation in the project afforded these students valuable experiences that translated into marketable skills leading to employment.

Lessons from the 2015/2016 Season

Digrius and Brunell recruited students from Stevens again in the Fall term of 2015 to participate in the multidisciplinary project overseen by Digrius and Brunell, but in this instance the setting for investigation was moved from Ecuador to El Salvador. Rural farmers living in poverty in the province of Chalatenango, in the village of Hierba Buena requested assistance in designing a sustainable water system that would provide potable water for their use. Currently, this community has no access to clean drinking water and must rely on suppliers to bring water into their village. In addition, they were looking for a more sustainable system of water management for their agricultural use. The reason for the shift in location was geopolitical, not due to any issues with the project, the students, or the design plan. Ecuador became increasingly less friendly to the United States after the death of Hugo Chavez and the asylum seeking of Julian Assange. Digrius and Brunell were able to utilize contacts with the Permanent Mission of El Salvador to the United Nations and locate an alternative setting for this year's work. Senior Design students were briefed on the current situation regarding water resources management in the region, their current access to those resources, and the breakdown demographically of the community, with particular attention paid to their education, age, and well-being.

To date, the students have been working closely with the demographic and geographic information collected thus far, and are in the process of completing a design plan for presentation to the community members of Hierba Buena in the Spring of 2016. They are developing a design which is modular and can be applied to numerous other regions of the world. Everything is sized based on anticipated rainfall/runoff and stakeholder demand. Digrius will travel to the community as a representative of the project and introduce the students' work to that community. What we have found thus far, is that the students feel more engaged with their work because it will have a positive impact on a group of people. They believe that this work can benefit others, bring a well-needed resource economically as well as socially to the community, and provide them with a level of empowerment that they would not have had if the project were not working towards these end goals. Finally, the students are learning about how their diverse skills in engineering can be applied in meaningful ways, answering to the call for engineering graduates who are technologically and socially prepared for the work force.

The CSU STEM Collaboratives Project

In response to the 2012 PCAST report mentioned previously in this paper, the Leona M. and Harry B. Helmsley Charitable Trust has invested $4.64 million in the California State University system to conduct a research project on student persistence and closing the achievement gaps in STEM. Beginning in May of 2014, campuses in the CSU could apply for funding to revamp strategies for supporting incoming first-time freshman into the CSU. Using integrated interventions using high impact practices (HIPs), the goal is to measure the impacts that these integrated high impact practices (Summer immersion experience, first-year seminar, redesign of introductory "gateway" courses) has on incoming first-year students. Two cohorts will participate in the initiative: one cohort entering the CSU in the Fall of 2015 and a second cohort entering the CSU in the Fall of 2016. Students will participate in a summer experience before they begin in the CSU, be grouped into a learning community and a first-year seminar, and be enrolled in a sequence of introductory courses that have an active learning component, supplemental instruction, peer mentoring, or other associated support structures.

One of the campuses, California State University Los Angeles (CSULA), had chosen to focus on their incoming first year students in Engineering, entering the College of Engineering, Science and Technology, (ECST) in Fall 2015. These students participated in a summer immersive experience that was modeled after an existing program (STEP), supplemental instruction using the UMKC model was applied, and students participating in the program were enrolled in the ENGR 500 course, a course that integrated collaborative and interdisciplinary design projects. Early indicators (the project cohort has completed their Fall 2015 quarter term) reveal that 100% of the FyRE engineering students at CSULA passed MATH 206, in comparison with 61% pass rate in the comparative Control Group for 2015, and a 58% pass rate among the historical group (F2014). In addition, their letter grade in MATH 206 was one letter grade higher than the comparison group (3.04 to 2.09). The FyRE students also had an overall GPA that ranked higher than the control group, at 3.17 as compared to 2.73 GPA. The students in FyRE were also surveyed about their experiences in the engineering program at CSULA, with all participants stating that they understood what is needed to be a successful engineer upon completion of the summer experience and the First Year Seminar. The authors believe that by integrating first year students into a research project such as *Sin el agua no hay vida*, given the similarities between the design component of the FYS in ENGR 500 and participation in some activities connected to *Sin el agua no hay vida,* an even higher level of engagement and persistence will result.

	Cumulative GPA	Std. dev	Math 206 GPA	Std. dev.	Math 206 pass rate
FYrE	3.17	0.60	3.04	0.82	100%
B206	2.73	0.67	2.09	1.05	61%
C2014	3.03	0.82	1.95	1.70	58%

Fig. 1. Data from CSULA that show engagement led to increased success in MATH 206.

Future Applications of this Work in Engineering Education

Mihelcic et. el., in their article "Sustainabiltiy Science and Engineering: The Emergence of a New Metadiscipline," discussed the development of a new field within sustainability science and engineering, one that "intgrates industrial, social, and environmental processes in a global context," (Mihelcic et. al., 2003). Using the metadiscipline as a model, Digrius and Brunell adopted the strategy that in order to achieve the educational and human resource needs necessary, "the technological and environmental awareness of society must be elevated and a sufficient and diverse pool of human talent must be attracted to this discipline," (2003). This project reinforces and promotes both of these strategies.

With the emergence of a metadiscipline, that integrates sustainability science and engineering, Digrius and Brunell see this work as integral to the development of engineering education that has relevancy for the twenty-first century. Employers desire a skillset that includes technical training and exposure to economic, environmental, and social objectives. Students participating in multidisciplinary, hands-on activities such as those in the *Sin el agua no hay vida,* project learn and are able to translate experiences into marketable outcomes. These students are literate in the technical skills that are required, but also the social awareness needed to address global problems. These students are desirable candidates for employment as sustainability gains attention in the engineering fields and in the global consciousness.

Engineering education in the twenty-first century requires more opportunities for active engagement in engineering design, particularly in the first two years of a student's academic experience. By combining the experiences of students at the outset of their experiences in an engineering program with later opportunities through their Senior Design projects, the authors feel that these activities will strengthen the students desire to persist and succeed into the upper division coursework. They also believe that by attaching the design activities with projects focused on sustainability, the likelihood is that historically underrepresented students will remain in discipline and graduate with an undergraduate degree in Engineering.

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Effectiveness of the Hybrid F2F/Online Model for Junior and Senior Engineering Courses

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Abstract
“Hybrid Face-to-Face / Online” is a name commonly used to describe courses in which some traditional Face-to-Face (F2F) "seat time" has been replaced by online learning activities. The hybrid F2F/ Online course model has the flexibility of fully online courses and the discipline of the traditional F2F in class courses. Hybrid courses are designed to integrate both Face-to-Face and online activities so that they reinforce, complement, and elaborate one another, instead of treating the online component as an add-on or duplicate of what is taught in the classroom. In this research study, the pros and cons of the hybrid F2F/ Online model are investigated. The proposed project employed a case study, which is utilized to compare the hybrid course model against the traditional Face-to-Face course model. The case study includes both a junior and senior engineering courses. The supportive roles of two different Fresno State professional development programs, DISCOVERe and eScholars, are discussed. The influence of both programs on the proposed hybrid model for both junior and senior courses is studied. The student evaluation, assessments and grades from two seniors courses and two juniors courses are used in this study. Fifty present (50%) of the courses are traditional F2F courses, while the other Fifty present (50%) of the case study courses employed the Hybrid F2F/ Online course model. The result of this study shows dramatically improvements in hybrid model courses while a higher improvement in senior hybrid model courses than the junior hybrid model courses.

Introduction

The hybrid F2F / online model was first introduced in 2001 as an efficient respond to high number of requests from nontraditional adult students, who seek a college culture that was counter to distance learning. The proposed hybrid model style has achieved more acceptances in many business programs and knows as “blended learning” [1]. There are several implementations to the blend learning that include pedagogical approaches, many technology modes and mixing instructional technology with face-to-face student and instructor interaction. The main challenge is to design the optimal mix course of online and F2F teaching that will achieve the major pros of asynchronous courses, i.e. any time and any place, and still maintaining the desired instructor-student interaction. There are many approaches being used to design an online learning program. However, they must inherit the culture of the adapting department in particular, and the collage or the university in general. Thompson Learning has conducted a two-year research case study. The case study has involved 128 learners from not only academia but also industry [2]. Three professors taught eight classes using the hybrid online model case study, which includes designing a blended curriculum that includes both online and F2F instruction. Another example, in Florida institution, several online options are offered, which include a F2F class that is technology dependent and fully online classes with no F2F interaction.

Figure #1 illustrates a visual representation of the hybrid model. The hybrid F2F/ Online Course model layout design composed of:

- A first class F2F Orientation meeting,
- Weekly online assignment,
- Synchronous on demand chat and online conference meeting,
- Asynchronous online threaded discussion, email, and
- A last F2F class, which usually includes Final exam.

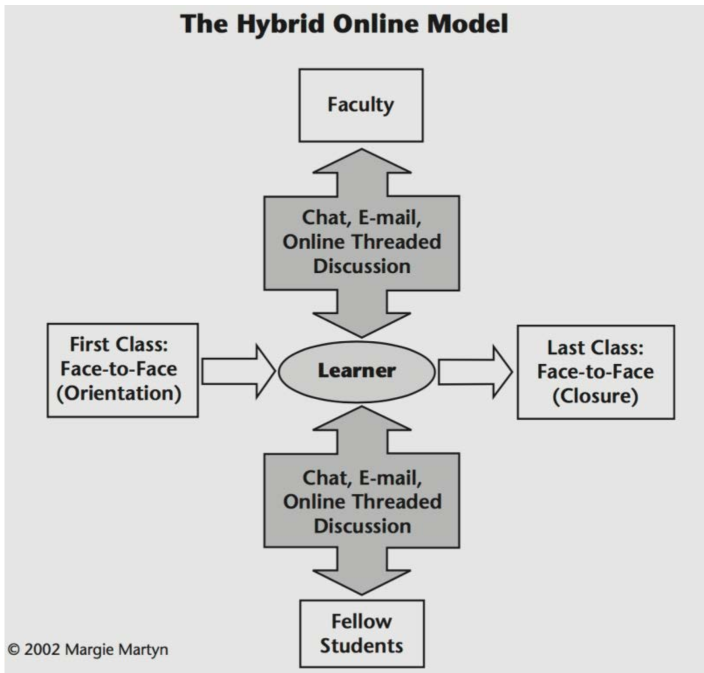

Figure #1 visual representation of the hybrid model [2]

This model has been demonstrating effectiveness for adult learners at many liberal arts colleges across the United States for many years. It provides an excellent way for institutions to enter the online arena and still ensure quality courses [5]. With the intention to enter the online education arena, the hybrid online model is introduced to computer engineering courses in California State University - Fresno. Utilizing couple of professional development programs that is recently initiated in Fresno State, the proposed study for comparing the hybrid model with the traditional F2F and the empirical results are discussed in this paper. Based on the outcomes and success of the presented case study, it is recommended to increase the number of hybrid online courses offered in years to come.

eScholars Program

"*Since 2008 the eScholars program has been transforming online course offerings through an active Faculty Development Program*"[3]

The eScholars Program is designed to support Fresno State faculties in the development of online and hybrid (>80% online) courses. After successful completion of the eScholars training program, not only they gain technical knowledge, but also faculty participants receive professional development funds of ($2,500) to help covering the course redesigning cost [3]. The eScholars training program includes attending a number of professional development activities, including but not limited to:

1. Group meetings and group discussions; in person and virtually.
2. Each faculty participant is assigned an instructional designer from Technology Innovations for Learning & Teaching (TILT) staff support as needed to complete a full functional online course conversion project and ensure accessibility of instructional materials.

The eScholars training program is not to be confused with the Online Boot Camp program. Both the training and the deliverable for Boot Camp participants are different from developing an online course in the eScholars program. The expected deliverable upon completion of eScholars training program is a completely redesigned and fully or mostly (>80%) online course. On the other hand, the online module being developed in the Boot Camp program can be utilized as supplemental to current course content and/or in lieu of face-to-face content. Accordingly, faculty participants retain ownership rights of all content created since the stipend is for participation in project-based professional development activities and it does not constitute extraordinary support under the Interim Intellectual Property Policy #540 [4].

All CSU - Fresno faculties can apply to any of the eScholars training program opportunities. However, the first challenge that a faculty member may have to handle is to convince his department chair and course coordinators with the potential offering of online or hybrid courses. As, eScholars training program acceptances require having some indication from the department chair and program coordinators that participant faculties are likely to teach the redesigned course during the semester following completion of the eScholars training program.

As an important part of Fresno State president Joseph I. Castro's strategic plan for excellence, the eScholars professional development training program directly addresses the strategically objectives stated in Theme #1 " *Enhance the Student Learning Environment* ". It clearly supports the faculty in utilizing innovative pedagogy, online delivery systems and emerging technological tools that enhance student-learning effectiveness. Additionally, it encourages and enhances exceptional teaching by introducing both state-of-the-art teaching technologies and instructional support teams to participant faculties who assist them with exploring innovative learning methodologies and techniques.

DISCOVERe Program

DISCOVERe is a tablet program being formally introduced to Fresno State University by president Joseph I. Castro early 2014. The goal of this tablet program is to facilitate student success both in content mastery and technology skill-set building. The Technology Innovations for Learning & Teaching (TILT) team is the primary facilitator of faculty support and training for Fresno State's tablet program. This team will partner with the Apple Development Team, existing faculty experts, Technology Services, and the Henry Library to provide training and on-going support for the faculty members. The benefit from this support is to help faculty in redesigning their courses using tablets technology. The Faculty Learning Community has many goals to achieve. These goals include discussing the pedagogical implications of tablets in higher education, becoming proficient with the iPad Air and the core apps, beginning the course redesign process, and finally determining core apps for in class use [5].

Moreover, the faculty should participate in one-week intensive institute mainly during summer. The expectations form the faculties who are attending the Summer Institute (SI) are to use the tablets in an actual classroom environment, develop expertise using the apps they will actual use in the classrooms, and to continue the course redesign process. As with other course redesign efforts at Fresno State, faculty will have access to many resources to support their course redesign. These resources include: Instructional Design, Technical Support from TILT, Technology Services, Multimedia Creation, which is including captioning of video content, Faculty Experts, and External resources as needed [5].

Case Study

The student evaluation, assessments and grades from a senior course and a junior course are used in this case study. Each course was offered during Fall 2014 using traditional F2F courses. Furthermore, each of the case study courses has employed the Hybrid F2F/ Online model during Fall 2015. The study case uses the outcomes from the same junior introductory course but was offered in two different semesters, i.e. Fall 2014 and Fall 2015. Accordingly, we used the outcomes from the same senior advanced course, which also was offered in two different semesters, i.e. Fall 2014 and Fall 2015. In this study, both the hybrid F2F/ Online course model and the traditional F2F are used for the junior "*Digital Logic Design*" course and the senior "*Advanced Computer Architecture*" course. Both courses are core courses for computer engineering major students. Balancing the number of enrolled students in each of the different course offering was challenging. Fresno State's faculty members usually have limited control over the number of students enrolled in their classes. The maximum classroom capacity is the main limit to control the ceiling number of the enrolled student in any offered course. On the other hand, they have also limited rule when it comes to recruit more course enrollment. Table # 1 shows the number of students enrolled in each of the case study courses.

Table #1 Student enrollment in ECE 85 and ECE 174 during Fall 2014 and Fall 2015

Course \ Offering Semester	**Fall 2014**	**Fall 2015**
ECE 85 Digital Logic Design	44	30
ECE 174 Advanced Computer Architecture	15	34

While both of the case study courses are mediatory courses for the students who are working on completing their degree requirement in Computer engineering. On the other hand, both courses are offered as elective for students in Electrical Engineering program. The catalog description for the " ECE 85 *Digital Logic Design"* course states: "*Discrete mathematics, logic, and Boolean algebra. Number systems and binary arithmetic, combinatorial logic and minimization techniques. Analysis and design of combinatorial circuits using logic gates, multiplexers, decoders, and PLD's. Flipflops, multivibrators, registers, and counters. Introduction to synchronous sequential circuits and state machines*." [6].

Furthermore, the catalog description for the "ECE 174 Advanced Computer Architecture" course states: " *Prerequisites: ECE 115 and ECE 118. Advanced computing architecture concepts: pipelining; multiprocessing and multiprogramming; cache and virtual memory; direct memory access, local and system bus architectures; instruction set design and coding; CPU and system performance analysis*." [6].

Figures # 2, 3, 4 and 5 are summarizing the numeric evaluation and letter grade for all students enrolled in all of the case study courses.

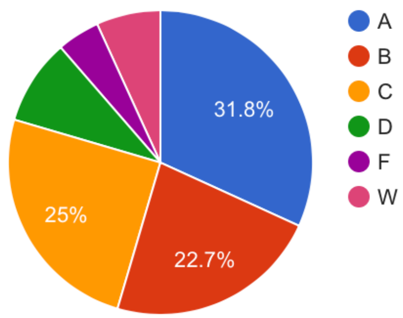

Figure # 2 ECE85 Fall2014 offered under F2F model

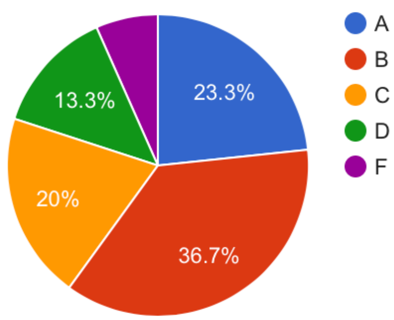

Figure # 3 ECE85 Fall2015 offered under the hybrid model

From Figures # 2 and 3, both the F2F course model and the Hybrid course model, which were employed for the junior design course, show that about 80% of the enrolled students were able to score more than 70% (C or better) in the final course grade. However, the number "A" students in the F2F course model was decreased in the Hybrid model course by 8.5 %. On the other hand the "B" students in the Hybrid model course were increased by 14%. From students feedback documented in the IDEA forms, the reduction in the number of "A" students was due to what I personally like to call "*technology shock*". Clearly, the hybrid course model requires from the enrolled student a higher level of technology adaption as most of the online and cloud activities utilize high tech tools.

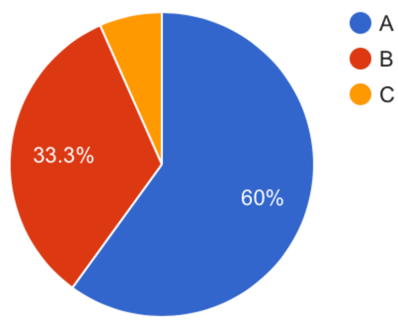

Figure # 4 ECE174 Fall2014 offered under F2F model

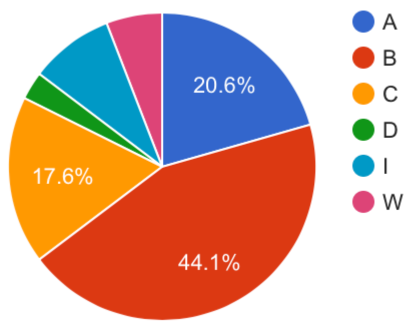

Figure # 5 ECE174 Fall2015 offered under the hybrid model

As illustrated in Figures # 4 and 5, both the F2F and the hybrid course models, which were employed for the senior design course, show that over 80% of the enrolled students were able to score more than 70 % (C or better) in the course grade. However, 39.4 % of the number students were not able to score an "A" grade when the hybrid model was employed. Also, from students feedback documented in the IDEA forms, the dramatically reduction was a result to the challenge of changing the teaching style during the students' senior stage. On the other hand, the "B" students in the hybrid model course were increased by 10.8 %. Furthermore, changing the teaching methodology by introducing the hybrid course model to senior students is introducing a new learning discomfort.

Conclusion

The F2F and Hybrid course models were employed in both junior and senior computer engineering courses. The preliminary results show a balance in the student success rate with 80 % of the students achieved a grade of "C" or better in both course models. However, a noticeable reduction in the number of "A" students was recorded when the hybrid course model was used for junior and senior courses. The reduction was blamed, according to the IDEA student feedback forms, to the technology adaption challenges in both junior and senior engineering courses. As Future work, the discussed case study will be scaled up to include more introductory and advanced courses. Sophomores students' courses will be add to the case study test bench. Repeated offerings of the current case study courses will be added to enrich the empirical results. We are currently designing an advanced student evaluation methodology, which will use the assessment for each of the learning outcomes to improve the case study's statistical data.

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Atomic Force Microscope as a Teaching Tool on Helping Students Understand Small Scale Structure of Materials

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Abstract

This paper presents the education experience in using an atomic force microscope to teaching students structure assessment knowledge. A Bruker Innova atomic force microscope (AFM) has recently been established in the Department of Mechanical Engineering at Cal Poly Pomona. The Bruker Innova Atomic Force Microscope with the capability of scanning probe microscope, conductive atomic force microscope, and magnetic force atomic microscope. It is possible to update the system to show atomic level resolution with later upgrading. The Bruker Innova Atomic Force Microscope comes with the vibration isolation table with the compact size of 600×600 mm, which is easy to install and easy to relocate for large population of student research training and education. The major activities of using this powerful instrument as a teaching tool include follows. First as a lab demonstration, undergraduates in the ME 350L (Engineering Materials Lab) and ME 220L (Strength of Materials Lab) know how to examine the microstructures of materials at nanoscale. Second, image capture practices were conducted for a group of international students at undergraduate level from Brazil to understand how the nanoporous alumina forms in an electrochemical oxidization process. Finally, several groups of senior capstone design students used the atomic force microscope to do focused studies on structure assessment of materials for energy production and conversion with low carbon output. Specifically, composite nanotubes and nanofibers for thermoelectric energy conversion were investigated using the atomic force microscope. Knowledge of electrical conductivity mapping at micro- and/or nanoscale were obtained for student at various levels using the conductivity measurement function of the Innova AFM. The electrical conductivity mapping results are interpreted to students to examine the size dependent transport behavior of nanocomposite materials.

Introduction

An atomic force microscope (AFM) uses a tiny and sharp tip to tap or touch the surface of the specimen. Atomic force microscopy (AFM) is classified as a kind of scanning probe microscopy (SPM). The resolution of AFM is at the sub-nanometer scale or angstrom level[1]. The magnification in an atomic force microscope is the ratio of the actual size of a feature to the size of the feature when viewed on a displaying device. There are different work modes. AFM may run under either contact mode or non-contact mode (tapping mode).

Under contact mode, the scanning tip is attached to the end of a cantilever across the specimen surface while monitoring the change in cantilever deflection with a split photodiode detector. The tip may contact the specimen surface through an absorbed fluid layer on the surface. A feedback loop maintains a constant deflection. According to Hook’s law, the magnitude of the atomic force can be calculated, which is at the level of nano-Newton or micro-Newton. The vertical distance the scanner moves at each pixel is stored to form the topographic image of the specimen's surface. Typically, the contact mode is used for imaging hard and shallow surface, the structure with periodicity, or the specimen in liquid environment. Under a non-contact mode or tapping mode, the cantilever is oscillating near or at the resonance frequency. The oscillating amplitude is in the range from several tens to one hundred nanometers. The tip lightly taps on the surface of the specimen when the scanner moves. A feedback loop maintains a constant oscillating amplitude. The vertical position of the tip is measured at each pixel of scan to generate the topographic image. Comparing the contact mode and the non-contact mode, there is difference in the resolution of the image. The contact mode allows to generate much higher resolution images. However, the tapping mode maintains a constant tip-specimen reaction. The tip has less chance to be struck or broken. Besides, in the contact mode, the tip scratches the surface of the specimen. This may cause the deformation of the surface of those soft materials. The images obtained could have some extent of distortion.

AFM may also run in the so-called phase mode. The work mechanism is based on the fact that measuring the phase shift of the cantilever beam holding the AFM tip is carried out instead of detecting its resonance frequency change. The phase mode is unique in the fact that it can generate material composition information. Even though the surface of a specimen is flat, if the material consists of different phases or functional groups, the surface mapping results can reflect the phase/composition information. For example, the vibration phase shift of the AFM tip generated by CH_3, and COOH can produce clear AFM images of certain polymers with significant contrast revealing the locations of these functional groups. Based on the AFM technique, there is a derived instrument for atomic level structure characterization. That is scanning tunneling microscope (STM). A scanning tunneling microscope (STM) works under the following mechanism. A very fine tungsten tip made through electrochemical etching is positioned within a couple of nanometers above the surface of a specimen. The positioning is controlled by a piezoelectric transducer that mechanically responses to the change in applied voltages. Since the precise control allows the tip to move at angstrom steps, images of atomic arrangement of a surface can be generated by sensing corrugations in the electron density of the surface that arise from the positions of surface atoms.

Due to the small separation between the tip and the specimen surface, electrons "tunnel" through the gap according to the principles of quantum mechanics. If a voltage is applied between the tip and the sample, a tunneling current can be detected. The tunneling current could be very small if the tip and surface separation is high. But with the reduced distance between the tip and the sample surface, the current increases exponentially. This makes the tunneling current detectable. As the tip scans the surface, corrugations in the electron density at the surface of the sample cause corresponding variations in the tunneling current. By detecting the very small changes in tunneling current as the tip moves across the surface, a two-dimensional map of the corrugations in electron density at the surface is obtained.

The Instrument used for Education

The Bruker Innova Atomic Force Microscope with the research capability of scanning probe microscope, conductive atomic force microscope, magnetic force atomic microscope is shown in *Figure 1*. It is possible to update the system to show atomic level resolution with later upgrading. With the capability of the instrument, we can perform all contact and tapping SPM modes like AFM, STM, LFM, FMM, CAFM, SThM, MFM, EFM, SCM and Electrochemical AFM/STM without changing and removing the scan head and the scanner, some modes may require optional purchase. The Innova includes LiftMode™ which is a patented imaging mode for improved MFM and EFM performance. In the Liftmode technique the sample's topography is determined on a continuous first pass over a scan line. The data are stored and a second parameter, such as magnetic field, is then determined by an amplitude or phase shift of the cantilever vibration on a second pass of the same scan line. This is accomplished by lifting the probe a set, but short (e.g., 50nm) distance above the surface. To guarantee correct lift-mode imaging, it has to be possible to use closed-loop z to achieve the desired lift height. Then, while using the stored data from the first pass scan, the exact topographical changes along the scan line are tracked while monitoring and storing the cantilever's interactions with magnetic forces emanating from the sample's surface. The MFM and topography images then get displayed simultaneously in real-time as acquired line-by-line. Other methods, e.g. which simply skim the tip some height above the sample without regard to topography are not acceptable.

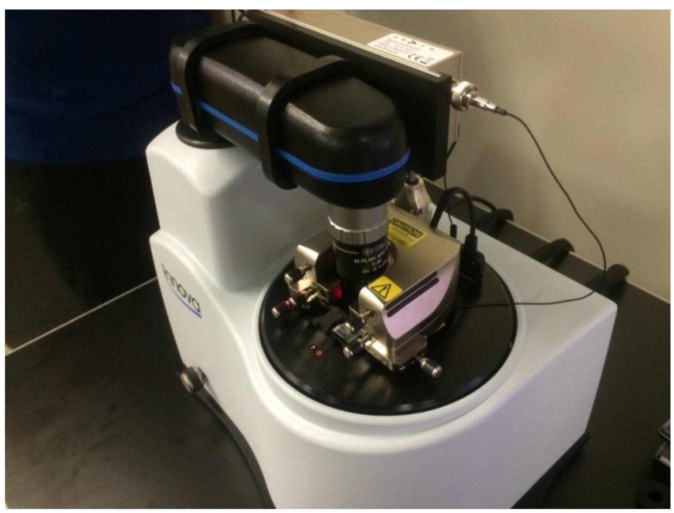

Figure 1: Photo showing the Bruker Innova atomic force microscope (AFM)

Context of Learning and Education

Nanoprous anodic aluminum oxide (AAO) template mapping was conducted and trained two Citrus Community College students, thirteen international students from Brazil in 2015 Summer Research Camp. There are many research reports on AAO template preparation, for example, by Zhao, Chen, and Zhang et al.[2] and Kong[3]. In the summer research, a two-step anodic oxidization method was used to obtain nanopores with uniform size and thin barrier layer. High-purity aluminum sheets were anodized on a single side using a regulated DC power supply in a 0.5 M oxalic acid solution. Before anodization, the aluminum plates were first degreased in trichloroethylene for 2 h, followed by 10 minutes of ultrasonic cleaning in acetone. Then the samples were rinsed with methanol and distilled water, respectively. After that, the aluminum plates were etched in 5.0 M NaOH at 60^oC for 20 minutes and subsequently rinsed with distilled water. Electropolishing of the aluminum plates was conducted in a 30% HNO_3 methanol solution at -20^oC. Anodization was performed in 0.3 M $H_2C_2O_4$ at 0^oC held in an icy water bath. The cleaned and electropolished aluminum sheets were used as the anode and Pt foil on graphite plate as the cathode. The first anodization took about 2 hrs. After the first anodization, the strip-off process was carried out in a mixture solution of H_3PO_4 and H_2CrO_4.

The exposed and well-ordered concave patterns on the aluminum substrate act as a self-assembled mask for the second anodization process. The second anodization took about 4 hrs. After the second anodization, AAO templates with uniform nanopores will be obtained for electrodeposition of nanofiberous arrays. The depth of the nanopores was controlled in the range of 750 nm to 1000 nm, and the diameter of the pores will be controlled in the range of 50 nm to 100 nm as shown in *Figure 2*.

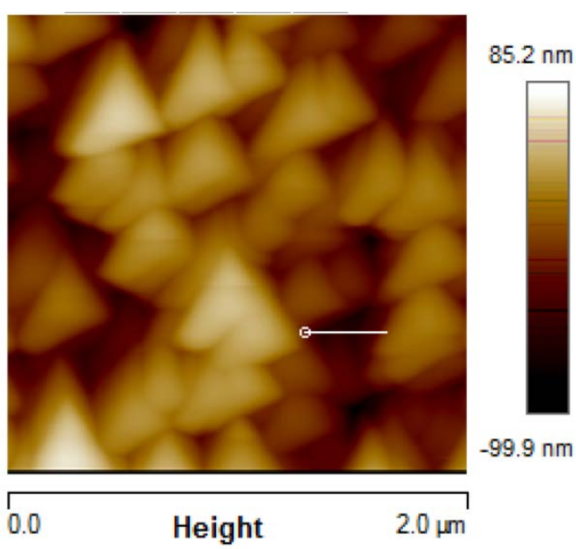

Figure 2: AFM image of the AAO porous material

In addition to the research training, in-class demonstration was performed. Students enrolled in Winter Quarter 2016 for the two lab classes, ME 350L (Engineering Materials Lab) and ME 220L (Strength of Materials Lab), got the chance to learn how the AFM works. For example, a quick calibration on the imaging system was shown and provide students the knowledge of imaging. We used *Figure 3* as the demonstration image.

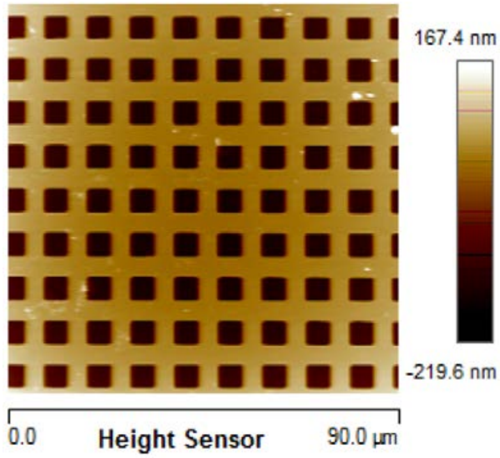

Figure 3: AFM image of gold-coated micro-pattern

Just recently, the AFM was used as a demonstration instrument in the Engineering event: Honors Showcase of Excellence on January 30, 2016. College applicant got a chance to see the capabilities of imaging, measurement of lateral motion forces and friction at atomic level.

Conclusions

Based on the research training, outreach and education experience in using the atomic force microscope to teach undergraduate students, the following conclusion remarks can be made. A model instrument can open the view of students through both the demonstration and the hands-on research. Students obtained structure assessment knowledge by practicing on using the AFM, which enhances the knowledge of what they learned from the early classes such as Engineering Materials, Strength of Materials, etc. In view the future effort, learning outcome assessment will be one of the important aspects for quantitative evaluation.

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NASA Sponsored Student Research Experience in Cloud Computing

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Abstract
Student research experience is very important in computer science education. We have funded by NASA to support students conduct research on cloud computing to improve students' learning experience. This group-based collaborative project not only enhance students' motivation, confidence, problem solving skills, but also help students to apply their knowledge learned from classrooms in a real world research project, prepare students for their career in IT industry, NASA and aerospace industry. This paper discusses our experience of this project and the outcome of the project. We also discuss the assessment of the performance of the students in during project implementation, including communication skills and development skills.

Introduction

Cloud computing is an internet-based computing. Users can access data storage, computers, software services, and other computing resources through web-based systems. The NASA is at the forefront of transitioning its science allocation to the cloud due to the advantages of (1) increasing flexibility of computing systems that can dynamically make adjustment and instantly meet the demand changes, and (2) more reliable computing services and decrease maintenance cost by supporting automatic software updates. In addition, it will decrease NASA's carbon footprint by reducing energy consumption since the centralized computer servers will save spaces and more efficiently support dynamic configuration.

With NASA support, our ongoing cloud computing project attracts graduate and undergraduate students to conduct research in cloud computing areas. This project helps us to provide cutting-edge educational and research opportunities for students. It also helps our undergraduate students to pursue graduate studies and to seek careers in the cloud-computing related areas. This NASA sponsored project focuses on the needs of NASA and Aerospace industry. Its goal is not only to improve students' motivation, confidence, resilience, problem solving and critical thinking skills, but also to improve students' communication, writing, and collaborating skills. This project also provides the students many opportunities to apply the concepts of software engineering and systems engineering that they learned in classrooms to develop system and software that are reliable, flexible, maintainable, and that works efficiently in a real world project. This project helps to train students to use knowledge and skills of software development to implement large-scale software systems with the current available tools.

Computer science program in Department of Computer Science at California State University Los Angeles is ABET accredited. The industry sponsored projects plays an important role in the evaluation of output of the computer science program. Assessment data derived from our NASA sponsored project can be used to evaluate the program Objectives/ Learning Outcomes based on the project implementation. The Objectives/Learning Outcomes of Department of Computer Science at California State University, Los Angeles (2016) directly related to our project are:

1. *Students will have the training to analyze problems and identify and define the computing requirements appropriate to their solutions.*
2. *Students will have the training to design, implement, and evaluate large software systems working both individually and collaboratively.*
3. *Students will be able to communicate effectively orally and in writing.*
4. *Students will have the knowledge, skills, and attitudes for lifelong self-development.*

The assessment of these outcomes is based on the faculty's evaluation to the project design, development skills, and written communication skills, such as the preparation of documents, including requirement specification, design specification, source codes, project report and presentation, and publications. The faculty member also evaluates the oral communication skills of students when students give presentations at the research seminars.

Team Formation and Education Goals

Graduate students and undergraduates are selected per year to join the hands-on and project-based learning research and study group. These graduate and undergraduate students working as research assistants get scholarships and start in September at the beginning of the new academic year and finish at the end of June the following year. These students also have opportunity to work at JPL as summer interns.

Baun, Kunze, Nimis, and Tai (2011) pointed out cloud computing technology is based on web based dynamic IT services. To join the research group, the students have to finish some prerequisite courses, including Using Relational Databases and SQL, Object-oriented Programming, Programming with Data Structures, Web and Internet Programming, Data Structures and Algorithms, Software Engineering. Through learning these prerequisite courses, students are expected to master a main programming language, such as Java, and database manipulating and operating language SQL and have some basic concepts of web-based programming and network knowledge. Students are also expected to have skills to specify the requirement of the system and use methodologies and tools for the specification, design, development, testing, evaluation, and maintenance of systems. Astin's (1985) and Oseguera's (2002) studies show that students can learn more through participating in group activities, spending substantial time in labs and interacting with faculty. Astin's (1982) studies also **show** that groups are very helpful to students. Our group-based NASA project encourages students to be more active learners and to spend more time with peers. In this way, it greatly improves students' research skills and system development abilities and increases their interest in pursuing careers in NASA and aerospace industries.

Our NASA project targets to enhance student research skills, such as self-study skills and to improve their written and oral communications skills expected in large system development. In this project, faculty member has direct opportunities to advise and evaluate students' oral and written communication skills. Increased student-student interaction is a key of group project success. Guo's (2009) report shows hands-on project development experience involved with real world project is very important to the computer science education. From the NASA project, the following benefits are expected:

- Improved students' system development experience.
- Enhanced students' problem solving skills.
- Students trained to master a set of comprehensive computing skills and to apply them in real world projects and systems.
- Students trained to have the ability of learning and updating their knowledge to keep the pace with new technological advancements in the academic research community and IT industry.
- Students trained to have teamwork collaboration and coordination skills.

To achieve our goals and objectives, the research students are grouped into a team and supervised by the faculty member. The team is responsible for creating models and developing the project collaboratively. The team meets with the faculty member weekly in the lab. Students are also required to attend the research seminars monthly. The group activities prepare participating students for interactive learning, practical system development, leadership roles, as well as to function and work in group environment. The approach provides several successful mechanisms for students. These mechanisms include: collaborative group-based learning communities, student-student relationships, project advising from faculty, and oral and written presentations. Guo (2009) reported that group-based collaborative project not only improves student performance, but also increases student motivation, confidence and resilience. This approach provides graduate and undergraduate students with hands-on learning experiences in the group. The faculty member selects students to join the research group. The students need to work collaboratively with peers. The team has a student as the group leader, who is in charge of coordinating the tasks between group members. Group members are required to participate in the group activities, such as requirement eliciting meeting, design review meeting, meeting with peers in the lab daily and meet with faculty member once per week. During weekly meetings, the participating students and group leader give brief presentations of current progress and discuss the existing issues and challenges with faculty member.

At the end of the first quarter, students have to submit a written report, including a work progress report and literature review report. The faculty member gives a ranking (1 – 5) in the five categories: Collaborative development, Oral Communication, Written Communication, Research Skills, Research Contribution. At the end of second quarter, students have to submit the system design report. And, for third quarter, students have to submit source codes of the system, deployment document, and final project reports. At the end of the year, students are expected to have following abilities:

- Perform concept studies
- Develop operation concepts for a project.
- Determine the feasibility of a project.

- Estimate the effort for a project.
- Make schedules for a project.
- Elicit requirements, including functional and non-functional requirement
- Create flow models, system hierarchy models, interface block diagrams, data models , and behavior models to specify functional requirements
- Convert requirement models into system architectures based on different architecture style patterns, such as data centered style, pipeline style, interpreter style, and implicit invoke style.
- Implement component-level design and develop components according to standards.
- Choose proper system testing strategies and use testing techniques, especially for integration testing and validation testing.

Goals of Cloud Computing Research

At the end of year, the students, who participate in the NASA project, are expected to possess skills and competencies in cloud computing areas, system development processes and system design applicable to cloud computing based systems. The skills and competencies are listed below.

- Cloud Computing Technologies: the students must have a thorough knowledge to apply cloud computing technology to solve NASA and aerospace industry problems:
  a. cloud computing platforms, tools and techniques for modeling and simulating systems;
  b. cloud computing models, such as Infrastructure as a service (IaaS), Platform as a service (PaaS) and Software as a service (SaaS)
- System Development Processes: the students must have the concept and knowledge of system life cycle to plan, evaluate, develop, and manage large project:
  a. feasibility assessment, requirements determination, system design, system implementation, and project management,;
  b. concept and technology development of cloud computing based systems via prototyping and simulation.
- System Design: The students must have knowledge to design systems, which meet the mission critical requirements of NASA and aerospace industry:
  a. requirements elicit and specification, system architecture development, system component implementation, system integration and verification;
  b. system structure and design involving cloud-based computing, such as service oriented architecture and computing;
  c. assessment of the benefits, costs, risks for different system architecture and design alternatives.

Through working on the NASA project, students are well trained to follow the systems engineering approach. The systems engineering approach played an important role in the project implementation. The students create a schedule to implement the project followed the systems engineering process with faculty member's help. This master schedule includes the major phases, tasks, activities and milestones of the development of the project. The students make this plan with the software tool MS Project under the instruction of the faculty member. In the Materials Collection and Concept Studies Phase, students collect, read, and study cloud computing related materials. In the meanwhile, faculty member gives several presentations during the weekly meetings to cover the cloud computing topics related the project.

In the Concept and Technology Development Phase, students and faculty member discuss the details of the QoS of cloud computing. Existing systems and technologies are reviewed. The flow diagrams of operation are developed based on the discussion of weekly meeting. System and subsystem requirements are developed. A detail project description is produced and major technology approach is determined. In the System Design and Technology Development Phase, prototyping and visualization technologies were used to build dataflow models, data models, and use case models. These models are the fundamental basis to refine the concept of operations during project development. Based on these models, the system is decomposed into subsystems and the system architecture is developed. In the meanwhile, the students learn and develop the related technologies. In the System Implementation and Development Phase, students focus on system detail design and implementation, such as data collection agent design, data persistent storage design, and data visualization design. Based on these detail design, students implement the components and perform unit testing. A lot of details of technologies are discussed during weekly meeting during this phase, including data representation, database schemas, communication protocols, distributed technologies.

		Task Name	Duration
1		NASA QoS Project	174 days?
2		Materials Collection and Concept Studies	17 days?
3		Materials Collection	7 days?
4		Concept Studies	7 days?
5		Concept and Technology Development	17 days?
6		Develop Concept of Operations and Technical Approach	12 days?
7		Develop System and Subsystem Requirements	6 days?
8		System Design and Technology Development	50 days?
9		Refine Concept of Operations	20 days?
10		Decompose System and Develop System Architecture	30 days?
11		Develop Related Technologies	40 days?
12		System Implementation and Development	63 days?
13		Complete Detail Design	20 days?
14		Data Collection Agent Design	11 days?
15		Data Persistent Storage Design	11 days?
16		Data Visualization Design	20 days?
17		Software Componenet Implementation/Unit Testing	51 days?
18		Data Collection Agent Implementation/Unit Testing	50 days?
19		Data Persistent Storage Implementation/Unit Testing	44 days?
20		Data Visualization Implementation/Unit Testing	51 days?
21		System Integration and Validation	32 days?
22		System Integration and Integration Test	25 days?
23		System Integration	14 days?
24		Develop System Integration Plan and Procedures	3 days?
25		Complete System Integration	11 days?
26		System Integration Testing	5 days?
27		Develop System Integration Test Plan and Procedures	3 days?
28		Complete System Integration Test	5 days?
29		System Validation	5 days?
30		Verify System vs Requirements	3 days?
31		Perform Validation Test	3 days?
32		Verify Deployment and Operations	2 days?
33		Perform Depoyment and Operation Test	2 days?
34		System Deployment	2 days?
35		System Platform Installation	2 days?
36		System Deployment	2 days?

In the System Integration and Validation Phase, the components developed and implemented in the previous need to be integrated. During this phase, the integration plan and procedure are developed, and then integration is completed. After that, integration testing and system validation need to be performed. System Deployment is the last phase. System platforms and running environment need to be setup and then system needs to be deployed.

Project Assessment

Assessment is a very import part of the NASA sponsored project. Student assessments included their levels of participation, such as attendance of weekly meeting, monthly seminars and group discussion, grasp of the project related materials, evaluation of laboratory activities, contribution to the project, and faculty member and peers evaluations. Scriven (1991) and MacDonald (2005) suggested the project assessment consists of two parts. The first one is formative evaluation, which is used monthly throughout the project. The second one is summative evaluation, which is used to evaluate how the project is meeting its goals at end of each quarter.

The learning outcomes of the project are based on students' research experience and the project development and implementation. The assessment focuses on if students have improved their research skills and ability of system design and implementation after the project and have the ability to work independently and collaboratively. This assessment is not only base on the faculty's evaluation to the whole project design and development progress but also based on the faculty's evaluation and peer's evaluation on research skills, critical thinking skills, and oral/written communication skills of students.

To evaluate student performance, 6 performance indicators and five scales are used:

Performance Indictors	**Related Criteria**
Project Life Cycle	Understand the concepts of project life cycle phases, incremental development phases. Be familiar with the engineering activities in the project life cycle, includes decomposition and definition sequence, integration and verification sequence. Have knowledge of spiral development and rapid prototyping models. Have ability to divide a project into life cycle phases. Produce a plan for different phases. Be familiar with deliverables and milestones for different phases of a project.
Concept and Technology Development	Understand the concepts of system requirement analysis technologies. Have knowledge of analysis models, including data flow models, system behavior models, and data models. Be familiar with use case and scenario analysis approach, activity diagram, and sequence diagram. Produce system requirement document with clearly defined and understandable functional and non-functional requirements.
System Design and Technology Development	Understand the concepts of system design process. Have knowledge of system architecture design and component design. Know how to convert requirement models into system structures. Be familiar with system component design approaches and component diagram. Know about data persistent design and establish proper relations between data models. Be aware of different system architect level patterns and system component design patterns. Produce system design document with functional requirement track matrix well defined.
System Implementation and Development	Understand system development and implementation principles. Have knowledge of system development tools and environments. Know how to implement system architecture and component level design. Be familiar with one or two mainstream programming languages. Be able to evaluate available frameworks, libraries, and thirty party tools. Know how to apply system design patterns. Be aware of different programming styles and standards. Produce well structured, easily understood and maintained software code.
System Integration and Validation	Understand the concepts of system integration, validation and verification process. Have knowledge of unit testing, integration testing and validation testing. Be familiar with available testing tools and environments. Produce system testing plan, procedures and testing report.
System Deployment	Understand the concepts of delivery and installation process. Have knowledge of system deployment procedures. Be familiar with the concept of system configuration. Produce system installation manual and configuration manual.

To evaluate the impact of the project, student surveys are conducted after each project seminar monthly. Besides those surveys, Guo (2010) reported that students' feedback on the experience of the research project and their self-assessment of learning experience are very useful. Below data are also collected.

- Improved Students' Ability to Work Collaboratively Survey (ranking 1 to 5) includes:
  1) Students' interaction and collaboration improved
  2) Students' self-motivation improved
  3) Students' communication skills improved
  4) Students' teamwork coordination skills improved
- Trained Students to Design and Implement Large Systems Survey (ranking 1 to 5) includes:
  1) Students' understanding the system development process improved
  2) Students' design skills got improved
  3) Students' developed practical skills of cutting technologies
  4) Students' problem solving and critical thinking skills improved
  5) Students' gained hands-on skills
  6) Students' became more confident on working on projects

Challenges for Students and Faculty

Faculty member takes a lot of responsibilities as an advisor. An advisor is a coordinator, who helps students to understand the scope and requirement of the project, helps students to make a reason plan and schedule, helps students to setup reason goals, and helps the team decompose the project into small manageable subsystems. An advisor also has to manage and help the team in effective ways. A good way is to setup goals for each week and make sure the students make progress toward the goals every week. The faculty also need help team to setup reasonable goals, schedule and deliverables for every month. So, the students know the deadline for each step. Microsoft Project is very good tool to setup reasonable goals, schedule and deliverables. It also helps advisor to track the progress. The most difficult aspect of being an advisor is to make all students involved and work efficiently, especially, there are always some students are not willing to work hard. Their attitude easily makes other students frustrated and slows down the whole project. Sticking on weekly meetings is an important approach. Each student has to report his progress in front of other students. If necessary, faculty should give warning to those students, who do not work hard enough.

Specifying system requirements is always a challenge for students since it involves a lot of domain knowledge. A lot of training, seminars, lectures, and meetings are important approaches to improve performance. Some tools are very helpful for students to capture the concepts of the project. Another challenge for students is system architecture design for large and complex system. Faculty member always has to involve in the system level design and help students to decompose large system into smaller modules and create system architecture. System architecture diagrams are very useful at this phase.

Learning and using new technologies is also an important aspect for the success project. As design and implementation of the project involves some technologies that students have not touched in their classrooms, students should be encouraged to learn and use the new technologies. Weekly meeting is also good time for students to discuss what they have learned in last week. Students are also encouraged to use the tools, products and technologies from third parties so that they do not start everything from sketch.

Conclusion

The project trains and stimulates students to pursue career in NASA and aerospace industry. The students also can improve their computing science and cloud computing education and enhance their opportunity for employment in IT industry. The NASA project not only provides students to participate in real project development process, but also prepares students to matches their real work required in future. The project not only provides students real industry experience, but also gives them opportunities to apply the fundamental systems engineering principles that they learned in classrooms to effective system and process design. They also need learn how to trade the project functionalities with efficiency, cost, schedule, customer preference, especially how to complete project on time and within budget.

This hands-on NASA project development enhances students learning experience by engaging students in structured, project-based collaborative group advised by the faculty. This project encourages students to be more active learners and to spend more time with peers. This is the essential of our goals to increase the motivation, confidence, collaboration, self-study abilities of the students. This project helps students to pursue their careers in NASA, aerospace industry, IT industry, and related fields and to participate in cooperative system development process, and to improve their problem solving and critical thinking skills in system design and implementation.

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Inception and Evolution of a Capstone Design Symposium

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Abstract
The purpose of this paper is to provide a description of the inception and evolution of an engineering capstone design symposium. Senior capstone courses in Aerospace Engineering and Mechanical Engineering (AE/ME) instructed at Embry-Riddle Aeronautical University, Prescott campus (ERAU/Prescott), are two-semester sequences consisting of a Preliminary Design course and a Detail Design course in either Aeronautics, Astronautics, Robotics, Propulsion, or Energy Engineering design. Students enrolled in these courses form design teams to create a design, usually in response to a Request for Proposal or a Requirements document; these teams then analyze, manufacture (or program), and test their design. At the end of each semester, each team is required to give a formal, public briefing to a panel of industry experts from organizations such as Lockheed Martin or Honeywell, as well as to the general public. These formal briefings typically last an hour, require that all students address the audience, may include a demonstration of the design (e.g., a maneuvering satellite floating on an air bearing or video of a successful flight test of an unmanned aerial system demonstrator), end with a public defense of questions asked by the experts, and are the final deliverable of the semester. As such, these capstone briefings are typically scheduled for the final Friday of the semester.

Introduction

Historically, ERAU/Prescott offered a handful of capstone courses, and scheduling of all the capstone briefings in a single auditorium was possible. However, with the rapid growth of the AE/ME program, such a simplified schedule became untenable. Moreover, there was a push to better publicize the success of this burgeoning program by using the capstone briefings for educational outreach to the surrounding community of Prescott, AZ. Thus, the AE/ME faculty redesigned the capstone briefings from a string of isolated presentations into a campus-wide event: an engineering symposium, complete with a daylong poster session.

The first objective of this paper is to describe the historical development of the capstone briefings into the AE/ME Capstone Symposium, and its further development into the campus and community highlight that it has become, complete with visits from the AE/ME Industrial Advisory Board and from College of Engineering alumni. A discussion of the factors that motivated the adoption of this time- and labor-intensive but rewarding event is also included. The second objective of this paper is to provide a brief description of the latest iteration of the symposium, focusing on the capstone projects presented and the work involved both to prepare for the event and to reach out to the surrounding community. Finally, recommendations will be made for those engineering programs planning to begin their own symposium. No event of this scope proceeds without certain missteps and the authors intend to help symposium organizers steer clear of similar missteps, as well as offer strategies that have proven successful for the AE/ME Capstone Symposium at ERAU/Prescott.

Context

ERAU/Prescott is a 4-year university located in Northern Arizona with an enrollment of approximately 2200 undergraduate students. The two most popular engineering degree programs are Aerospace Engineering (AE) and Mechanical Engineering (ME). Within the AE/ME curriculum, there is a strong emphasis on hands-on application and conceptual design projects to prepare students for senior capstone design courses. Students majoring in AE or ME must choose one design track: Aircraft or Spacecraft for AE's and Propulsion, Robotics or Energy for ME's. Each track culminates in a sequence of two senior design courses: Preliminary Design and Detail Design. In each of the Preliminary Design courses, students work in teams to perform conceptual and preliminary design of an overall system. In the Detail Design courses, each team typically selects a set of subsystems from their preliminary design and performs physical testing (e.g., wind tunnel testing, structural testing, flight testing). These test results are then compared to computer-based simulations and are documented in written reports, informal presentations, and a final formal capstone briefing. Throughout the two-semester design process, students receive instruction from both their engineering professor and a technical writing professor from the Department of Humanities/Communications embedded in the capstone class; both instructors in this team-teaching arrangement help students learn how to document their work, effectively work in teams, and effectively present their findings at the end of each semester.

Up until a few years ago, there were only a few sections of capstone at ERAU/Prescott, and so all AE/ME students could give their final briefings in the campus auditorium during a sequence of day-long presentations at the end of each semester. However, as enrollment in the AE/ME program grew to over 500 (over 30% of the campus student population), scheduling all the required presentations in one location was no longer tenable; moreover, the College of Engineering began to see the presentations as a means of public outreach to the broader Prescott community. The following sections will provide an overview of the history of the AE/ME Capstone Symposium, from its inception in Fall 2011 through its evolution to its current iteration.

Inception of the AE/ME Capstone Symposium

As mentioned in the preceding paragraph, a major impetus to the introduction of the symposium was the growth of the AE/ME Program, with multiple design teams from Aeronautics, Astronautics, Robotics, Propulsion, and Energy Tracks all requiring a venue to provide their final capstone briefings. However, the idea itself actually sprang from the instructor of single Robotics team in Spring 2010. Dr. John Nafziger had led his team through the development and testing of a Lunabotics rover which performed extremely well at a NASA competition, and he wanted to show off their work. Since the auditorium where the capstone presentations had been held in the past did not lend itself to such a demonstration, John decided to split with tradition and reserved a large classroom in our Academic Complex adjacent to an atrium where students and visitors could better observe the rover. John also had his team create several posters documenting the evolution of the design; his students placed these posters around the rover in the atrium. While other capstone teams presented in the auditorium, the team provided their final presentation to a packed classroom. His team then invited the attendees to join them in the atrium where they proceeded to perform demos and further explain their design. This interactive experience was extremely successful, and led the remaining capstone instructors to rethink the best possible venue for their teams' final presentations.

Through a subsequent series of meetings, the capstone instructors developed a symposium idea, and the primary author of this paper (Prof. Jim Helbling) was tasked with organizing it. Since Dr. Nafziger's approach had been proven to be successful, Prof. Helbling modeled the symposium using two classrooms adjacent to the atrium for the presentations and the atrium itself for the poster session. These classrooms have a capacity of 60 seats, versus the auditorium which boasts a capacity of approximately 300. The 60 person capacity was judged to be adequate. The poster session would also allow attendees to review a variety of designs while waiting for their presentation of interest. An image of one of the 60 person classrooms being utilized for a capstone presentation is provided in the figure below:

Figure 1: Capstone Presentation Room

(As the figure shows, adequate seating is available for those wishing to view the presentation being given. In Fall 2011, the logistics for the inaugural symposium were addressed.)

First, Prof. Helbling worked with his fellow capstone instructors to define a set of questions which would be used by the industry and faculty panelists to evaluate the capstone teams. These questions were chosen to address the following ABET Outcomes (ABET, 2014):

- Outcome c: Ability to design a system, component, or process to meet desired needs.
- Outcome d: Ability to function on multidisciplinary teams.
- Outcome k: Ability to use the techniques, skills and modern engineering tools necessary for engineering practice.

The panelist responses were used as a part of a metric to evaluate the capstone courses relative to ABET requirements.

The next issue involved coordinating a schedule with the capstone instructors. Through a series of iterations, a schedule was chosen which allowed for a sequence which made sense chronologically (i.e., Preliminary Design courses before Detail Design courses within the same track), and allowed students with interest in a given area maximum opportunity to attend the presentations of their choice. Once the schedule was set, Prof. Helbling met with the director of the Media Services organization to ensure that a PA system was installed in both classrooms and a video camera manned by a technician was also scheduled so the briefings could be archived. Of note, that the auditorium which had been used in the past had a built-in PA system and camera system, which negated the need for this coordination. Next, Prof. Helbling developed a floorplan for the posters that maximized the use of the available space within the atrium. Since the Detail Design teams typically have hardware to display along with their posters (e.g., an unmanned aerial system or a robotic system), additional space was allocated for those teams. Finally, Prof. Helbling coordinated with the campus Facilities Department to ensure that any existing furniture was removed from the atrium, and that the correct number of tables and chairs were delivered to allow students to display their hardware and sit when no visitors were present. An image showing a portion of the general layout of the poster session is shown below:

Figure 2: Poster Session Image

(As can be seen in the above image, students are primarily stationed around the center of the atrium, allowing visitors to move freely around their perimeter.)

The Fall 2011 symposium was judged to be very successful based on feedback received from students and their families, instructors, and campus leadership. However, it was obvious that certain changes needed to be made to improve on the experience in subsequent semesters. These changes, and others which were implemented over the years, are documented in the next section.

Evolution of the AE/ME Capstone Symposium

The first change that became very evident during the initial symposium was the need to coordinate industry panelists in the weeks preceding the symposium. Initially it was assumed that each of the capstone faculty members would perform this coordination task independently. When some faculty members made this task an afterthought, they discovered that visiting industry members had already committed to presentations scheduled at the same time as the faculty's. To alleviate this problem, Prof. Helbling took on the task of asking the pool of industry panelists (most of whom were members of the AE/ME Industrial Advisory Board) to provide their priority of the presentations they would like to attend. Prof. Helbling then assigned the panelists to the various capstone teams to ensure that nearly equal numbers of panelists were available for each team.

Another change was made to the media coverage of the presentations to address the more limited seating in the 60 seat classrooms. 50-inch flat screen television monitors were stationed in the atrium outside of both classrooms and fed a picture-in-picture video feed showing both the presenter and the slide they were presenting. Initially, the feed was video only, but later the audio feed was added. Adding this feature allowed visitors to watch and listen to the presentations being given without entering the rooms after the presentations had started.
An additional change became necessary due to the increase in the number of capstone teams following the growth of the AE/ME Program enrollment. This increase in enrollment is illustrated by Table 1: AE Program, ME Program and Campus Enrollments for ERAU/Prescott: Fall 2007 – Fall 2015, below:

Table 1: AE Program, ME Program and Campus Enrollments for ERAU/Prescott: Fall 2007 – Fall 2015 (ERAU Office of Institutional Research, 2016)

Academic Year (Fall)	Total AE Enrollment	Total ME Enrollment	Total AE/ME Enrollment	Total Campus Enrollment	AE/ME Program as % of Total Enrollment
2007[A]	511	12	523	1676	31.2
2008	549	32	581	1688	34.4
2009	499	38	537	1627	33.0
2010	496	50	546	1653	33.0
2011[B]	513	74	587	1672	35.0
2012	534	96	630	1678	37.5
2013	584	120	704	1813	38.8
2014[C]	638	137	775	1984	39.1
2015	686	161	847	2205	38.4

[A] First year that the ME program came online | [B] First year that ERAU/Prescott held its AE/ME Capstone Symposium | [C] First year that the Energy Track came online

The table above shows the steady increase in enrollment since the first symposium, and the increase in the percentage of overall enrollment of the AE/ME Program since Fall 2011. The increase in these values caused a three-fold change to the symposium: 1) an additional 35 seat classroom was added to the two 60 seat classrooms already in use for the capstone team presentations to provide an additional venue for briefings, 2) the floorplan for the poster sessions were adjusted to make use of all available space in the atrium to allow all of the capstone teams to display their work, 3) additional advertising was implemented to ensure that all students on campus were aware of the symposium and its contents. The additional advertising became necessary to address the larger student body, many of whom would be incoming freshmen who were as yet unfamiliar with the symposium. Both traditional (e.g., flyers) and social media (e.g., Facebook) were used to advertise the most recent symposium.

The last change to the symposium to be discussed in this paper involves outreach to the Prescott, AZ community. Over time, members of the community became overtly involved with the design projects, and therefore wanted to attend the symposium to see the entire design process presented. For example, the members of a local RC field offer the use of their field and RC equipment to teams that perform design, build, fly projects. Other community members are retired aerospace or mechanical engineers who offer their services as panelists for the presentations. Advertising for the symposium thus began to spread through the larger Prescott area by word-of-mouth. The symposium is also advertised on a new marquee located on a busy street that runs by the campus. To better illustrate the content of the ERAU/Prescott symposium, the following section provides a listing of the teams and projects from the Fall 2015 symposium.

ERAU/Prescott Fall 2015 Symposium Team Content

To indicate the scope of the projects that are presented in a single day by our engineering undergraduates during the AE/ME Capstone Symposium, Table 2: Summary of Capstone Presentations for Fall 2015 AE/ME Capstone Symposium is provided:

Table 2: Summary of Capstone Presentations for Fall 2015 AE/ME Capstone Symposium

Capstone Class Name	Project Description	Team Name	Team Members
Aircraft Preliminary Design	B-2 Replacement Aircraft	Daedalus Aerospace	9
	T-38 Replacement Aircraft	Turaco Aerospace	9
	Reusable Spacecraft to Launch Satellites into Orbit	Genesis	9
	Airplane To Launch the Reusable Genesis Spacecraft	LaunchTech	7
	Close Air Support Fighter	Fire 4 Effect	9

Table 2: Summary of Capstone Presentations for Fall 2015 AE/ME Capstone Symposium (cont.)

Capstone Class Name	Project Description	Team Name	Team Members
Aircraft Detail Design	Small Unmanned Aerial System (SUAS) – Traffic Surveillance	Iluvatar	10
	SUAS – Coast Guard Search & Rescue	Pelican	11
Spacecraft Preliminary Design	Planetary Lander	P.A.L.S.	17
Spacecraft Detail Design	Orbital Debris Reduction System	Sol Systems Engineering	11
	Planetary Lander	LSR Aerospace	13
Propulsion Preliminary Design	Thrust Chamber Assembly	Strava Designs	5
	Rocket Gimbal	ALoLE	2
	Ramjet + Rocket Booster Propulsion System	Viper Aerospace	6
	Engines for the Fire 4 Effect Close-air Support Fighter	More Than Enough Propulsion	5
	Disk Live Rim Slot Simulation for a Honeywell Engine	SEE++	5
Energy Preliminary Design	Solar Thermal Power-generating Rig	Aeos Energy	6
Robotics Preliminary Design	Outdoor Exploration Robot	Incurve	5
	Navigating Autonomous Robot to Collect Aquatic Litter	NARWHAL Robotics	4
	TOTALS	18 Teams	143 Seniors

As indicated in the preceding table, over 140 seniors on 18 teams presented their designs to the panelists and visitors as part of the symposium. To illustrate the growth of the symposium, the first symposium included 10 teams with fewer than 100 students.

Although these methods have proven to be effective in bringing community members onto campus on symposium days, more can be done in terms of effective advertising. Suggestions for these and other planned improvements are provided in the following section.

Planned Improvements

Although the symposium has been very successful and proven to be the showcase event each semester for the College of Engineering, there is always room for improvement. The following paragraphs discuss some of the planned improvements. As mentioned in the previous section, one means of improvement in terms of community outreach would be to advertise the symposium via both the local newspaper and on local radio. The budget for this advertising will be pursued through the college dean. Students could also be asked to speak to local community organizations and high schools to further the campuses STEM outreach.

Another improvement will involve expanding the current space allocated for the poster sessions and presentations to adjacent buildings. As previously mentioned, the AE/ME Program is continually expanding, and the poster session currently takes up virtually all of the space available in the atrium. An illustration of the current congested conditions is provided in the figure shown below:

Figure 3: Poster Session Space Limitations

The figure above shows how posters are placed on either side of a walkway, limiting traffic. Construction on a second Academic Complex adjacent to the first is scheduled to commence in April 2016 and will allow an additional venue for posters and presentations. The new buildings will be a short walk from the existing venue, and will allow visitors to visit a planetarium designed for STEM outreach.

One final improvement could be to follow the lead of undergraduate design symposiums offered at other universities and make the poster session competitive, offering prizes to teams who best present the design concepts. Several categories could be used, such as best graphics, best videos, or best hardware demonstration. Adding this additional incentive may inspire our students to make their posters and associated displays more imaginative and inviting to visitors. To further illustrate the symposium ideas that are currently offered at other universities, and compare their concepts to that offered at ERAU/Prescott, research was performed and documented in the following section.

Comparison to Symposia Offered at Other Universities

A brief review of engineering symposia held at other universities illustrates the unusual nature of the symposium discussed in this paper. Much like the AE/ME Capstone Symposium, most engineering symposia are daylong events with poster presentations and featured presentations. However, unlike the symposium at ERAU/Prescott, some universities (e.g., University of Michigan) showcase the work of graduate students, not of undergraduate students, and often serve double-duty as recruitment and admissions fairs for prospective graduate students (Michigan Engineering, 2016). Moreover, student participation is often restricted to poster presentations, and featured presentations are given by industry specialists, not by students or student design teams while other universities (e.g., Purdue) allow their undergraduates to give either a public briefing or a poster presentation of their research – but not both (Purdue University, 2015).

Those engineering symposia that do feature undergraduate research often feature poster presentations, as the AE/ME Capstone Symposium does. However, unlike the symposium at ERAU/Prescott, many of these undergraduate symposia are not structured around formal team briefings which require students to present their designs to industry panelists; instead, most undergraduate symposia are structured around the poster presentations (e.g., Arizona State University). Indeed, at some universities (e.g., University of New Hampshire), students enter their posters in a college-wide contest which is judged by faculty panelists (Arizona State University, 2016; University of New Hampshire, 2016).

Finally, the AE/ME Capstone Symposium is held twice a year. While some universities also hold their engineering symposia twice a year, most hold theirs annually (Bucknell University, 2016, University of Arizona, 2016). Regardless of whether participation is open to undergraduates or graduates, whether formal briefings or poster presentations are the highlight of the event, or whether the event is held once or twice per year, engineering symposia of all stripes allow engineering students to showcase their designs, share their work with the larger (academic or geographic) community, and refine their professional communication skills. The following section will offer recommendations to those interested in pursuing their own symposium.

Conclusions and Recommendations

The establishment of a capstone symposium can provide engineering students with opportunities to network with experts, showcase their work in both semi-formal and formal venues. The university can be provided with opportunities to connect with the larger community and publicize the depth of undergraduate research. The following suggestions are based on the experiences the authors have had in establishing and iterating the AE/ME Capstone Symposium at ERAU/Prescott and are offered to those program organizers who wish to follow suit:

1. Perform research on existing symposia to determine the scope which best fits your needs in terms of your capstone projects (perhaps starting with those cited in the following Bibliography section of this paper).
2. Organize a meeting with all capstone faculty to get their input and buy-in on the symposium idea. Discuss the content and format of the symposium based on the facilities available and size of your student body.
3. Obtain budget estimates from your facilities and media organizations and ensure sufficient funding is available. Be aware that additional funding may be required for food if an all-day symposium is held. For example, the Fall 2015 ERAU/Prescott symposium required an expenditure of $400 for pizza and drinks to feed the design teams, faculty, and panelists.
4. Include your Industrial Advisory Board in the planning process, and invite them to participate as either panelists or speakers.
5. Finalize plans with your media and facilities organizations at least one month prior to the planned symposium date. This early planning will allow for iterations (if necessary) and will provide a solid base upon which you can finalize other plans.
6. Advertise the symposium on local media, social media, and across campus to help ensure good attendance.

By following these basic steps, other universities may provide their engineering capstone students with the joy of sharing their work with others.

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Empirical Study for the Effective PBL Incorporating Conflict Management Model

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Abstract
Project-based learning (PBL), already in use at many educational institutions, is proving highly effective in encouraging students to take an active approach to their studies. Having said that, we do see cases in which students participating in a PBL team are hampered by a lack of project management knowledge together with a low level of leadership and group communication skills, a situation that often leads to conflict or a general loss of motivation as members come to feel that they are simply being told what to do. Here, it is expected that access to conflict resolution techniques for use within PBL would do much to enhance its educational effectiveness. In this paper, we propose a conflict resolution model for use in PBL and examine its effectiveness as applied to a college-level learning environment.

Introduction
A variety of conflicts are commonly encountered between individuals and within organizations, and project-based learning (PBL) teams are no exception. Not only can conflict be highly stressful for team members (and the end client or recipient of the outcome), but it can have a significant bearing on the ultimate success or failure of a project (Suzuki, 2008). Stress reduction is also an important element in enhancing the effectiveness of PBL in educational environments. We frequently observe cases in which students participating in a PBL team are hampered by a lack of project management knowledge together with a low level of leadership and group communication skills. This often leads to conflict or a general loss of motivation as members come to feel that they are simply being told what to do.

Notable research efforts in the area of conflict management include Takahashi, who reports on his work with the Thomas–Kilmann model (Takahashi, 1998, Robins, 1974). While positively assessing the manner in which Thomas integrates a process model and a structural model, Takahashi also points out the strength of psychological approaches. Takezawa reports on the results of research into conflict resolution among students engaged in group work (Takezawa, 2014). He constructs a logical framework for structural constructivism and proposes methods by which students within a workgroup can overcome conflict and methods by which conflict situations can be creatively utilized. Mizuno, in research on conflict management within organizations, focuses on conflict among nurses, for whom an ability to skillfully manage human relationships is of particular importance, and examines the effectiveness of management methods from the perspective of individual practitioners (Mizuno, 2007). Fujii et al. present the results of demonstrative research into conflict management within projects (Fujii, 2005). Ioi et al. present the proposal of fun-based leadership incorporating PC game analysis and development of fundamental competencies for working persons through project-based learning (Ioi, 2013 and 2014). Hanabusa present the way to make student activity successful (Hanabusa, 2014). Kizaki present build on the project manager training environment by international PBL environment (Kizaki, 2012). Tomiyama et al. present multidisciplinary education framework for social implementation of robotics (Tomiyama, 2015). In their research, they reveal situations likely to induce conflict and propose methods of handling conflict within the realm of project management. These and other researchers point out the importance of conflict resolution techniques and their proper application. Having said that, very few have touched on the question of conflict management within PBL.

In this paper, we propose a conflict management model to enhance the educational effectiveness of PBL. The model, which proceeds by project phase according to a conflict-resolution relational diagram, is intended to alleviate the stress felt by PBL participants. More specifically, the objective of our research is to do the following:

1) Apply the SECI (Socialization, Externalization, Combination, Internalization) model of knowledge conversion to the development and proposal of a conflict management model for application to PBL;
2) Demonstrate the effectiveness of our conflict management model by means of project management experiments involving college students within a PBL environment; and
3) Investigate the psychological aspects of efforts to enhance the educational effectiveness of PBL.

A Conflict Management Model for PBL

A conflict arising within a project, left unresolved, can develop into a serious problem. Likewise, negative responses—that is, responses that do not seek to resolve the underlying issue—may lead to the failure of the project as a whole. Positive responses, in contrast, can produce a desirable outcome. For instance, a conflict may give project members more opportunity to communicate among themselves, to speak openly and come to understand each other, and thereby, to reinforce the team and produce a better output. We introduce a conflict resolution relational diagram. It can be applied when, for example, team members have some difference of opinion among them or some dissatisfaction/uneasiness with the roles assigned. Here, the introduction of a new, related challenge, one that gives team members the ability to express a variety of opinions, would act to encourage communication among members and to foster self-understanding by individual members. This would provide them a sense of satisfaction (for expressing an opinion) and accomplishment (for resolving a problem). A notable feature of this approach is that it addresses not only the negative aspects of conflict, but also, as noted above, the positive aspects.

Figure 1 illustrates a conflict management model for application to PBL. Within the model, elements of the SECI process (as a knowledge conversion model) are applied according to PBL phase (startup, planning, execution, and conclusion) and the relevant conflict resolution relational diagram. In the socialization mode of knowledge conversion, stress resulting from discomfort or dissatisfaction among PBL participants accumulates as conflict-related tacit knowledge. In the externalization mode, accumulated knowledge is externalized as explicit knowledge for resolving the conflict. In this mode, free communication among team members supports the establishment and sharing of objectives and policies for conflict resolution together with the discovery of new issues. In the combination mode, externalized knowledge for conflict resolution is combined with a variety of views derived through PBL to create explicit knowledge for application to the conflict. Finally, in the internalization mode, practical knowledge pertaining to conflict resolution within PBL is accumulated and merged, thereby further adding to the store of tacit knowledge. Thus, through the use of a conflict management model within PBL, students are able to produce knowledge for application to resolution of conflict within each project management phase.

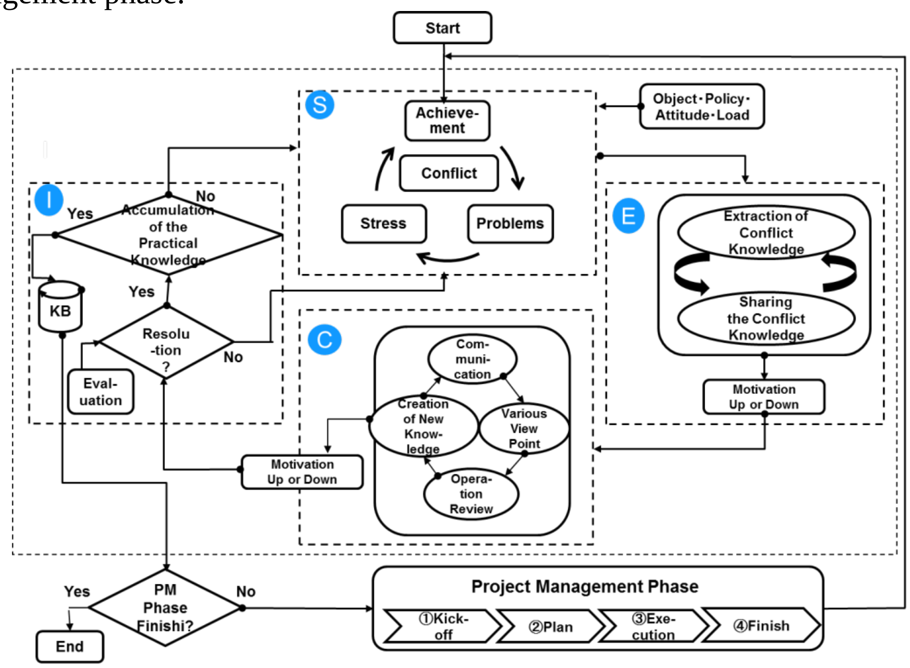

Figure 1 Conflict management model (Noboru Konno, 2005)

Verification of Conflict Management Model

In order to verify the effectiveness of our PBL conflict management model, we had college students conduct project management exercises within a PBL learning environment.

Conflict in PBL

Particularly in PBL activities involving college students, many of whom have little experience in or practical knowledge of project management, we find numerous potential sources of conflict. These include inappropriate communication, uneasiness resulting from differences of opinion, different perceptions of target level, a sense of being told what to do, difficulties in reaching consensus, a lack of trust in leaders or team members, uncertainties or concerns over the desired end product, inappropriate assignment of responsibilities, excessive workloads, and worries over how the “product” will be externally assessed.

Conflict in Project Management Exercises

To assess the effectiveness of our conflict management model within a PBL environment, we conducted several surveys during the course of a series of PBL project management exercises. Exercises of PBL project were carried out in two areas: software development and business creation. Here, we targeted our survey at students within the business creation area. In the PBL startup and planning phases, students first attend a lecture by a professor and then move on to a brainstorming session, where, by means of the JK method, they consider what they are to cover by case analysis and determine what type of business to propose. In the execution phase, they work to summarize their case analysis in preparation for an intermediate presentation. Following that presentation, they conduct various studies and surveys based on their case analysis and then summarize their conclusions in preparation for a final presentation. Each project team has three or four members, who work together over a 15-week period from project startup to conclusion. During the startup and planning phases, the students have yet to determine specific goals, and thus we would expect to see considerable conflict resulting from communication issues. Likewise, within the execution phase, we would expect conflicts—and, by extension, stress—to result from assignments of responsibility and associated imbalances in workload. As the final presentation and deadline for report submission draw near, we would expect conflicts to become more frequent as anxieties mount amid a diminishment in member performance and resulting delays in project progression. The stress resulting from such conflicts of the projects is classified as related to one of the following: people, deadlines and workload, information sharing, and the results/product.

Verification through Project Management Exercises

We took the project management exercises as an opportunity to survey project teams (denoted A and B here) to gauge the state of conflict within them. The various processes of a project management exercise are shown in Figure 2 and figure 3. Here, the processes from startup up to intermediate presentation are labeled as Planning 1, Execution 1, and Conclusion 1, in that order. Likewise, those from the intermediate presentation up to the final presentation are labeled as Planning 2, Execution 2, and Conclusion 2. For each of those phases, we surveyed the students about their stress, conflicts, motivation, performance, and communication on a 4-level rubric. The answers were used to assess the results (for the purposes of this research, we define PBL performance as action toward the achievement of the desired goal). On stress and conflict, a higher score indicates a stronger degree of stimulation or impact. Conversely, on communication, motivation, and performance, a higher score indicates a more favorable state. Thus, with regard to stress and conflict, we can easily determine their levels; while, with regard to communication, motivation, and performance, we see that the higher the score, the better. We see that the students participating in the project management exercise (a PBL activity) maintain a high level of motivation through all phases, from startup to conclusion. This holds true for both Team A and Team B, although we do note somewhat of a drop in relative motivation within Team A during the Planning 2 phase. This phase encompasses the first set of project activities following the intermediate presentation; presumably, the assessment given to the intermediate presentation had something to do with this motivational decline. As for PBL performance, both

Team A and Team B did well within their kickoff meeting (startup) and subsequent brainstorming sessions. Performance slipped somewhat afterward, despite a continually high degree of member motivation. This performance decline is presumably attributable to a low level of the basic project management skills required for successful PBL, a deficiency that frequently thwarts efforts to improve scheduling and communication. We did not expect stress or conflict to cause any major problems in these exercises because (1) PBL was to be conducted within a formal college class, (2) the teams were to be small, each having only a few members, and (3) both professors and teaching assistants (graduate students) were to be on hand to provide advice and support. This said, we did note a roughly saw-toothed pattern of conflicts as the teams advanced through their project phases. That is, the students did experience a variety of stresses and those produced conflicts. Those conflicts, however, were resolved without any major problems, only to occur again in a similar situation, a repetition apparently captured by this pattern. From the above results, we conclude that conflict actually gave the PBL team members opportunities for communication and so acted to strengthen the bonds of understanding among them.

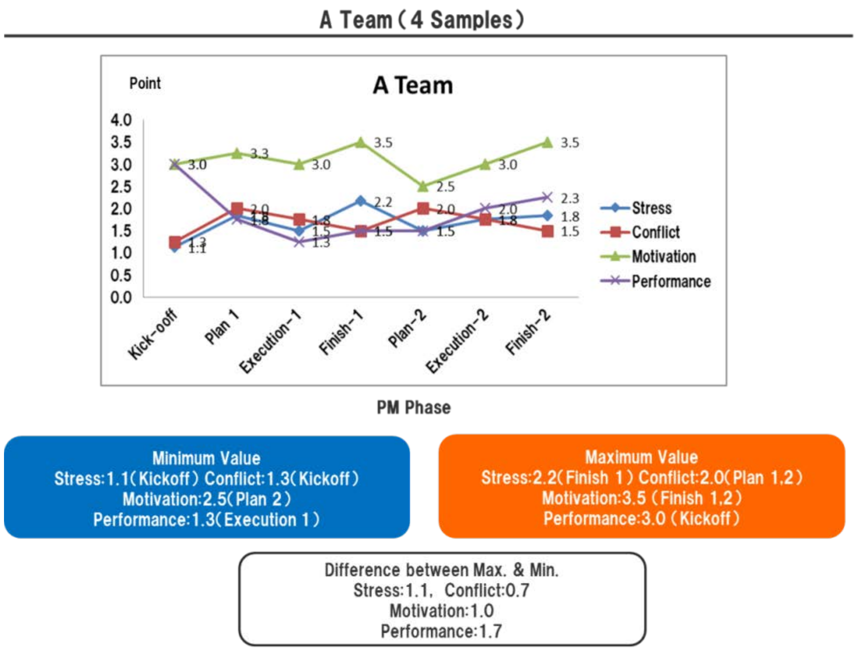

Figure 2 Experimental results on the conflict in the PBL for A Team

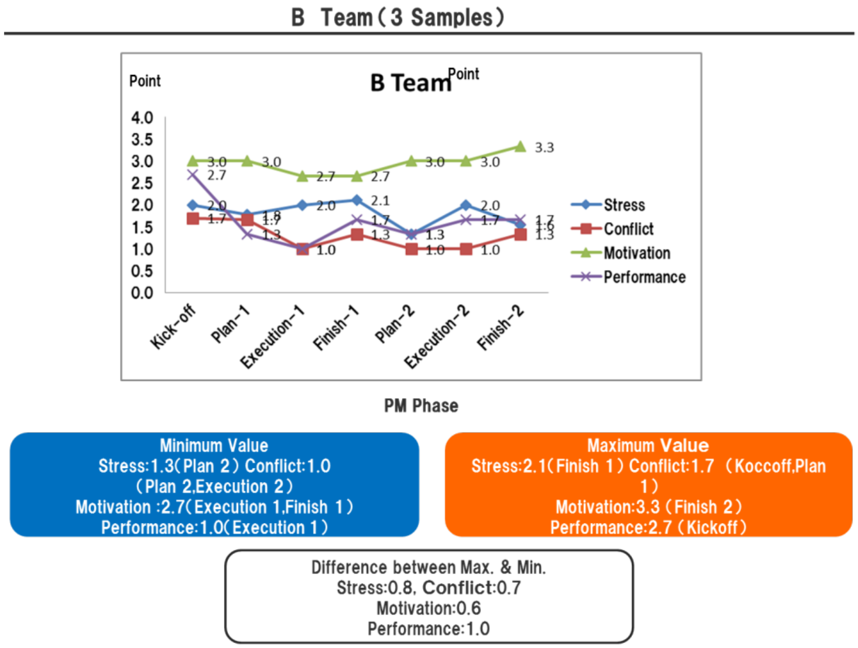

Figure 3 Experimental results on the conflict in the PBL for B Team

Resolution of PBL Problem Points

To more closely analyze the test results of Figure 2 and figure 3, we conducted a second survey, this one directed at 30 members of eight project teams within the project management exercises. First, we prepared 10 assessment items for those members. These items were based on the items earlier prepared for the members of Teams A and B. We divided into stress related to workload and team size; motivation was divided into sense of goal attainment, pleasure, and degree of anticipation; performance was divided into degree of goal attainment and results; communication was divided into self-realization, expression, and conformity. The self-assessment results are plotted on a percentage scale (full scale: 100%) in Figures 4 (A) through figure 4 (D), with the horizontal axes indicating the number of PBL team members. On goal attainment (A) and self-realization (B), we note a scattered plot ranging from 40% to 90%. In contrast, on expression (D), we see a very broad distribution that ranges from 0% to 100%. We also note a fairly wide scattering—that is, sizeable difference in perceptions among PBL students—for the other assessment categories: sense of goal attainment, pleasure (C), workload, number of team members, degree of anticipation, and results. From the results of the above testing, we find the following.

- The motivation of PBL students is high.
- Many felt a strong degree of goal attainment and, accordingly, a high degree of self-realization.
- Some students were easily swayed by their teammates' opinions, while others actively asserted their own. The presence of both types on mean teams resulted in a high degree of scattering on conformity;

- Some participants had very little to say, while others spoke out frequently. As with conformity, we note wide variation on expression.

Expectations, conformity, and workload can all be addressed within the framework provided by understanding from the field of psychology, such as the Pygmalion effect, the conformity effect, and the Ringelmann (loafing) effect. As the results, it is very important to introduce psychological factor at the PBL execution phases. If you consider the Pygmalion effects, the motivation of PBL students will be greatly improved. This, in order to facilitate communication during PBL, we conclude that it is also important to consider psychological factors. Figure 5 (E) through figure 5 (G) show the results of questionnaire on the workload, degree of anticipation and conformity. On workload (E) and degree of anticipation (F), we note a scattered plot ranging from 0% to 100%. On conformity, it was scattered plot ranging from 40% to 100%. It is considered as the reason of high looseness that the skills and consciousness of PBL students depend on independent. From viewpoints of psychology, work load, degree of anticipation and conformity are according to social corner cutting, Pygmalion effect and siding phenomenon respectively. We propose to introduce the psychological factors to get good communication and high motivation of the PBL member.

Figure 6 shows the proposal for the effective PBL based on this research. The graph is composed of the high consciousness zone, low consciousness zone and psychological factor zone. The psychological factors are classified into social corner cutting, Pygmalion effects and siding phenomenon. We can expect to reduce the looseness of each factor like workload, anticipation and conformity in the PBL if the psychological factor introduced into the PBL management.

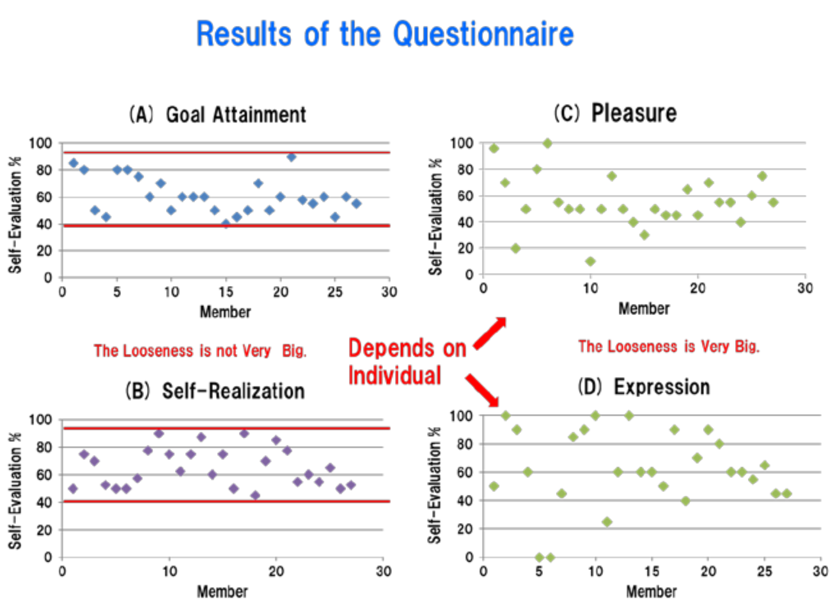

Figure 4 Behavioral Characteristics of the PBL Member

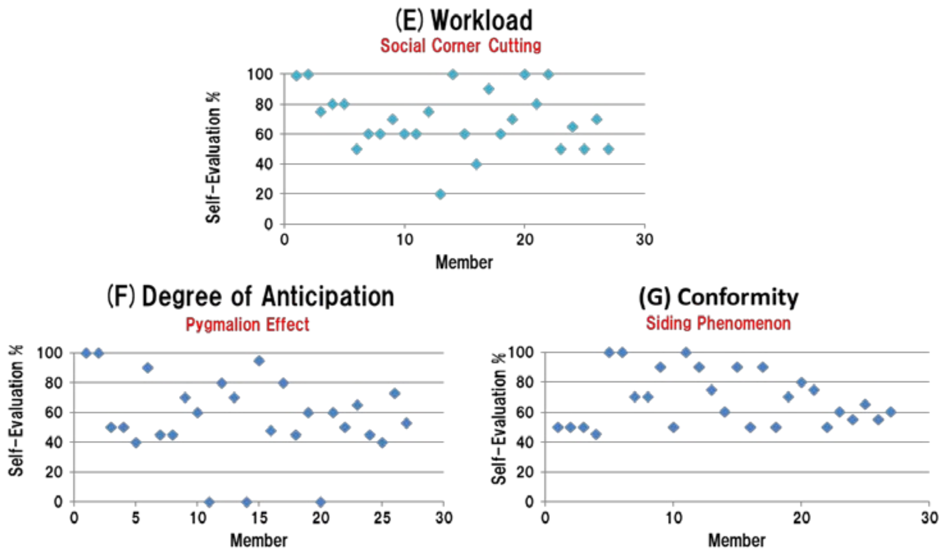

Figure 5 Behavioral Characteristics of the PBL Member related to Psychology

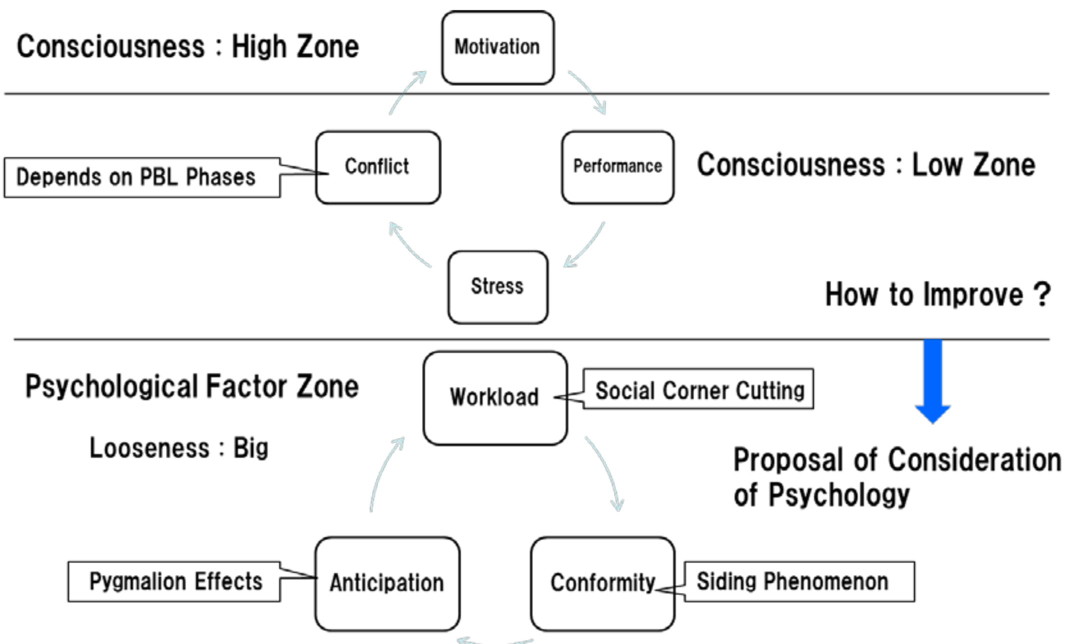

Figure 6 Proposal for the Effective PBL

Conclusions

For this paper, we proposed a model for conflict resolution for use within PBL and verified its effectiveness through project management exercises. From our results, we reach the following conclusions.

1) We were able to develop and propose a conflict management model that is based on the SECI model of knowledge conversion and applicable to the resolution of conflict within PBL activities.
2) By surveying student stress, conflict, motivation, performance, and communication in project management exercises conducted within a college-level PBL environment, we were able to verify the effectiveness of our conflict management model.
3) To enhance the educational effectiveness of PBL, it is important to also consider tools from the field of psychology, including those to mitigate the Pygmalion effect, the conformity effect, and the Ringelmann (loafing) effect.

Acknowledgment

The authors express appreciation to Mr. Kohei Kamiyama, a graduate of the Department of Project Management, for his assistance with the experiments described in this paper.

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Inquiry Based Learning Activities: Rolling Cylinders & Work-Energy

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California Polytechnic State University: San Luis Obispo

Abstract
Our research group is studying the effects upon learning Engineering Dynamics concepts in the classroom when using hands-on activities. The group consists of two engineering professors and a team of undergraduate Mechanical Engineering students. A set of Inquiry-Based Learning Activities (IBLAs) are conducted within the classroom where the students document their initial predictions of the activity, their observations during the experiment, and their reasoning for the behavior they witness. The basis to perform this in-classroom research is to evaluate if a personal experience with the physical phenomenon will help facilitate student learning, motivation and retention of engineering concepts.

In this paper, we present results from our Rolling Cylinders Inquiry-Based Learning Activity. During this IBLA, students are given a ramp and various solid and hollow cylinders of varying material: PVC, steel, aluminum and wood, and varying diameters to visually observe rolling objects. With these observations, students are projected to recognize the effect of mass moment of inertia and outer radius on the object's behavior. The worksheet filled out by the students while performing the activity prompt them to analyze concepts of work and energy to evaluate their observations, and also asks them to predict outcomes for other scenarios. Our paper will report how the IBLA is conducted, explore student explanations for their experimental observations, and report results on concept questions before the IBLA, two days after, and two weeks after the activity was completed.

Introduction
Historically, the method in which information has been conveyed from a professor to the student has been in a large lecture hall, where surrounded by fellow undergraduate students, the student has listened to an expert delivering content. While this is a cost effective and efficient way of conveying information to a large group of people, researchers wish to find a better way of "getting knowledge into the heads of their students." [Bodner, 1986] In his paper discussing constructivism as a theory of learning, Bodner states that "Teaching and learning are not synonymous; we can teach, and teach well, without having the students learn," which begs the question: what is a better method of instructing students so that they will internalize the concept and have a better understand of the world around them?

One possible solution to this lack of learning may be to teach students in smaller groups which allows for more personal interactions with the professor while the learning is taking place. A second solution might be to provide the information in a different manner, such as a physical student-to-concept interaction to promote exploration for an engaging experience. This non-passive, first person experience does still require the educator to be present so as to "provide structure and serve to monitor and promote learning while helping students confront misconceptions and knowledge gaps and improve thinking processes." [Bailey et. al 2011]

One University in particular, California Polytechnic State University: San Luis Obispo, has performed extensive research into this idea of changing the method in which information is conveyed to the student, especially in the undergraduate Engineering course, Dynamics. The emerging process is to allow students to explore a physical phenomenon through the use of an Inquiry-Based Learning Activity.

Background

Inquiry-Based Learning Activities (IBLAs) consist of presenting students with a physical situation and asking them to predict what will happen. After the students have made their own individual prediction, they join a group and discuss the scenario as a team. The students then investigate the situation by experimenting with physical hardware in a way that is specifically designed to demonstrate unexpected behavior and create cognitive conflict. The hardware therefore becomes the "authority" rather than the professor, thus forcing students to confront any misconceptions they might have (Widmann et al, 2014). Each IBLA follows the cycle depicted in Figure 1.

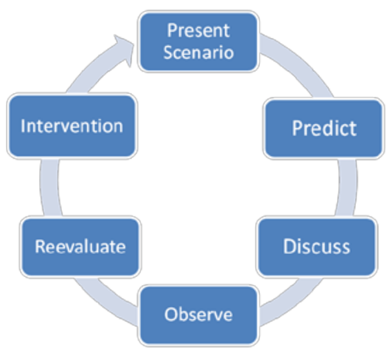

Figure 11. Standard IBLA Cycle

These IBLAs are implemented in the undergraduate Engineering course Dynamics, where students investigate particle and rigid body kinetics, kinematics, and the principles of work-energy and impulse-momentum. Students use their prior knowledge gained from the prerequisite courses, statics and physics, to analyze the various forces that a body may be experiencing, and use the newly acquired dynamics knowledge to analyze how this body will now move due to an imbalance in forces.

In the Rolling Cylinders IBLA, students are given a ramp, an elevation change, and a set of various cylinders to conduct several cases designed to highlight any misconceptions that the student may have brought with them prior to conducting the activity. A photo of some students performing this activity can be seen in Figure 2, where they begin rolling the cylinders at the same instant and observe the results of each case.

Figure 2. Students performing the Rolling Cylinder IBLA. [Georgette 2013]

The set of cylinders that are used in this activity are constructed from four materials: steel, aluminum, PVC pipe, and hard wood. This set contains cylinders that may weigh the same but have a different radii, may have the same radii but are of similar material, etc. The set of cylinders used can be seen in Figure 3, in no particular order. An equipment list can be found in Appendix A.

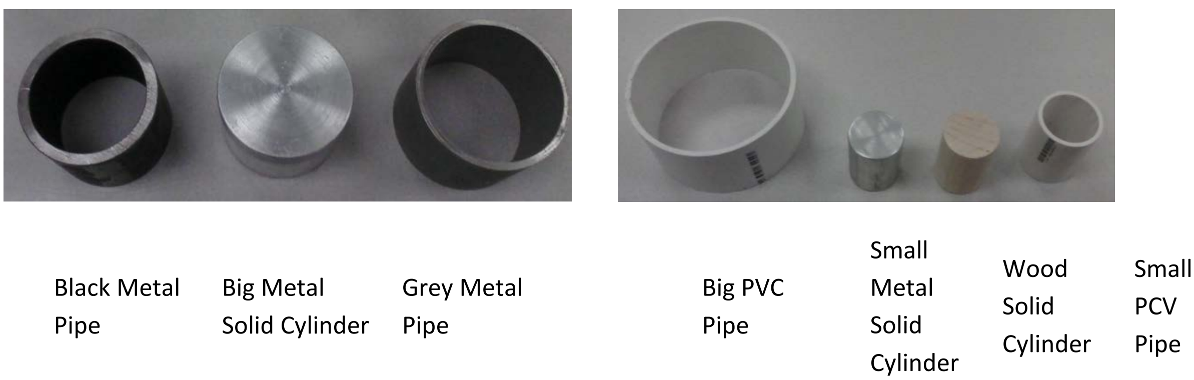

Figure 3. Set of multi-material cylinders used in the Rolling Cylinders IBLA.

Methods

The procedure in which the IBLA is as follows: the students are given an individual prediction sheet, Appendix B1, and are asked to complete Case A, which asks: of the black metal solid cylinder and the black metal pipe, which have the same radius and mass, which will roll to the bottom of the ramp first? After checking the box of the options: Big Metal Solid Cylinder, Black Metal Pipe or same time, the student is asked to write a brief explanation of their answer. This is followed by selecting from a range of confidence levels: Total Guess, Low-Moderate, Moderate, Moderate-High, and High. Upon completing these individual predictions, the students are asked to join teams and discuss their reasoning behind their expectations, and fill in a team predictions sheet, Appendix B2. They are encouraged to either hold to their initial reasoning or to change to a different option due to new information they may have gathered from a teammate.

The team is then asked to perform Case A and observe which cylinder reached the bottom of the ramp first, and as a team explain the results using dynamics principles. Following this explanation, the students are asked to choose the object that has the larger mass moment of inertia. The students are also asked to "Discuss the translational and rotational energy of the cylinder and pipe," "Which object has the larger translational kinetic energy when it reaches the bottom?" and "Which has the larger rotational kinetic energy?" The team then proceeds onto Case B with individual predictions and then come together again to repeat the process. The questions following Case B in the team worksheet are designed to stimulate the students to challenge any preconceived misconceptions about what they expected to happen and what actually occurred with the two solid cylinders with differing radii. Three more cases are presented, with the fifth and final case being one of self-exploration where the team will choose two to three different objects and run their own experiment.

During this activity, the professor and teaching assistants oversee the learning process and are able to provide aid when necessary. The student-instructor interactions are not based upon providing direct instruction, but rather on asking the students thought-provoking questions to guide them towards the correct conceptual understanding. For example, if the students roll a given set of objects and had inconsistent results, they would be asked to repeat the roll a few more times to make sure the correct conclusion was reached. [Georgette 2013]

The Dynamic's concepts that the students explore through this activity are those of Work-Energy and Mass Moment of Inertia. A most notable concept is that the shape of an object is the key component of the Mass Moment of Inertia and that this is what ultimately describes the motion observed. The opening case hopes to exemplify that when two objects are of the same radius, length, and mass but differing shape, behave differently when rolling. To analyze this concept the students are prompted in the team worksheet to explore different concepts of work-energy. The two conclusions that can be used to describe the phenomenon observed are that through applying the rolling without slipping principle, all solid homogeneous cylinders will have the identical linear velocities at the end of the ramp, *independent of mass and radius*, and furthermore, all cylinders will always reach the bottom of the ramp before all pipes, *regardless of the radius and mass*.

This is possible by examining the work-energy equation: $T_1 + V_1 = T_2 + V_2$, where T and V are kinetic and potential energy, respectively. If the cylinder starts from rest, T_1 = 0; for a given ramp, the change in height can be assumed to be the same for all the objects, so the base of the ramp will be chosen as the datum. Therefore, the equation can be rewritten as:

$$mgh = \frac{1}{2} I_G \omega^2 + \frac{1}{2} m v_G^2 \tag{2}$$

The mass moment of inertia can be expanded to be $I_G = cmr^2$, where c is a scaling factor. For a thin ring, $c = 1.0$, and for a solid cylinder, $c = ½$. Substituting the rolling without slipping condition, $v_G = r$ □:

$$mgh = \frac{1}{2}cmr^2\left(\frac{v_G^2}{r^2}\right) + \frac{1}{2}mv_G^2 \tag{3}$$

Solving for v_G, the mass and the radius both cancel, thus the linear velocity is independent of these parameters.

$$v_G = \sqrt{\frac{2gh}{1+c}} \tag{4}$$

Examining Eq (4), it can be seen that the linear velocity only depends on the Mass Moment of Inertia scaling factor: c. Therefore, a round object with a greater Mass Moment of Inertia will reach the bottom of the ramp more slowly than an object with a smaller I_G. It is hoped that the students will realize that this Mass Moment of Inertia factor indicates a distribution of mass and this leads to the variation is translational and rotational kinetic energy between differing shaped objects.

To help assess the IBLAs that take place during the quarter, the Dynamics Concept Inquiry (DCI) is taken at the beginning and the end of the quarter. This DCI (Gray, et al, 2005) allows for the opportunity to poll students as they just enter the Dynamics course, to observe their preconceived misconceptions, and also to observe the effectiveness of the instruction as they depart from the course. There are various questions in this multiple-choice assessment that sample the student's knowledge and understanding; where the specific question for the Rolling Cylinders IBLA is Number 12, seen in Figure 4.

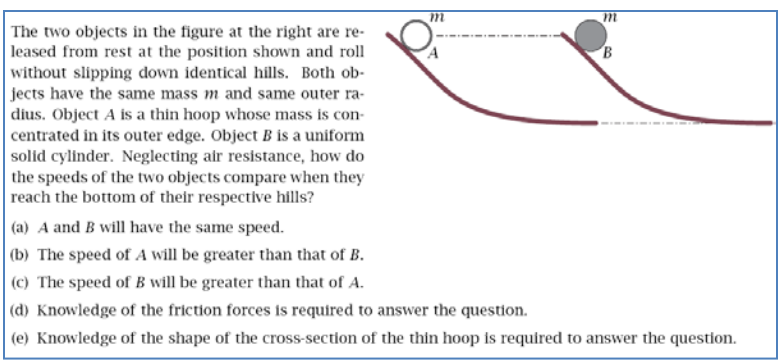

Figure 4. Dynamics Concept Inquiry Rolling cylinders applicable question. (AIChE, 2016)

Results

The following data is a summary of performing the Rolling Cylinders IBLA over five sections of the undergraduate Engineering course Dynamics; detailed data can be found in Appendix C. This data stems directly from Individual Prediction sheets and the Dynamics Concept Inquiry from the beginning and end of each quarter. In Figure 6 the summary of the individual predictions can be seen where a bar graph shows the comparison between correct predictions to incorrect predictions for each case. The overall number of students who provided responses was 268 students, and the percentage of correct predictions are 67% for Case A, 26% for Case B, 91% for Case C, and 27% for Case D. There are initially a high number of correct responses with a discernable decrease in Case B. There is a maximum number of correct responses for Case C, and then another noticeable decrease in Case D. A summary of the activity, organized case by case, can be found in Figure 5.

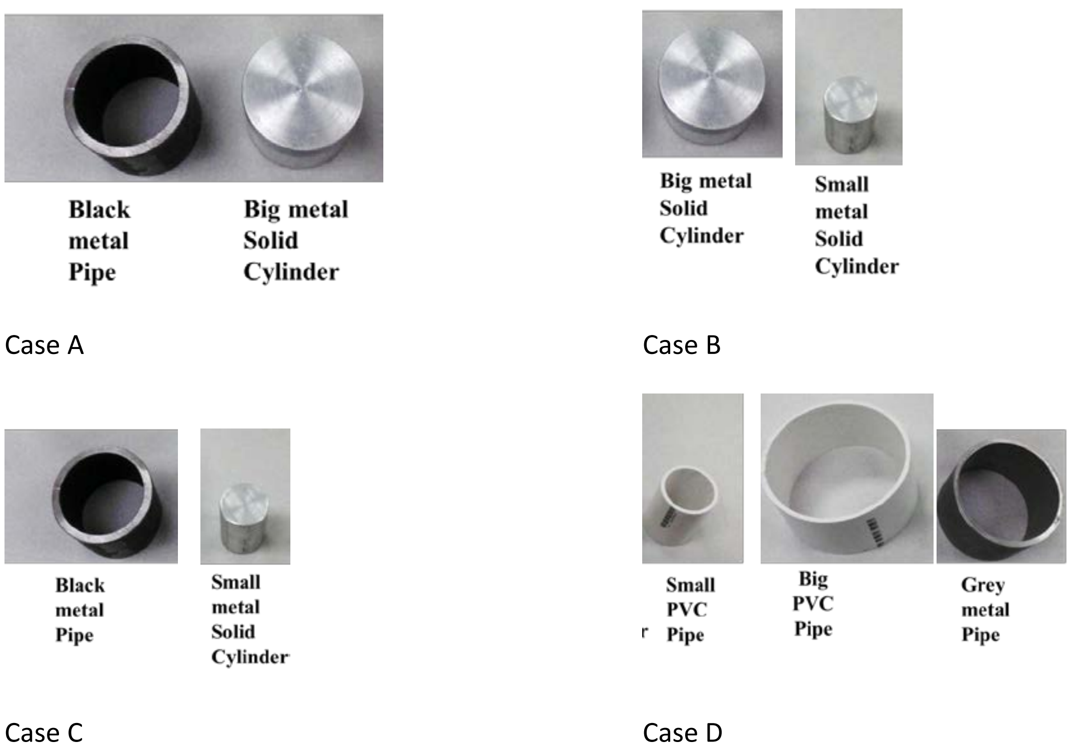

Figure 5. Summary of each case in the Rolling Cylinders IBLA.

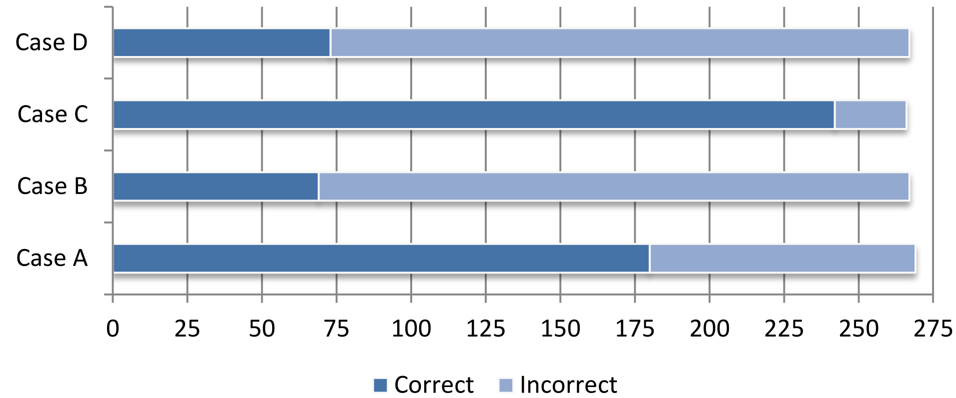

Figure 6. Summary of individual predictions for Cases A through D.

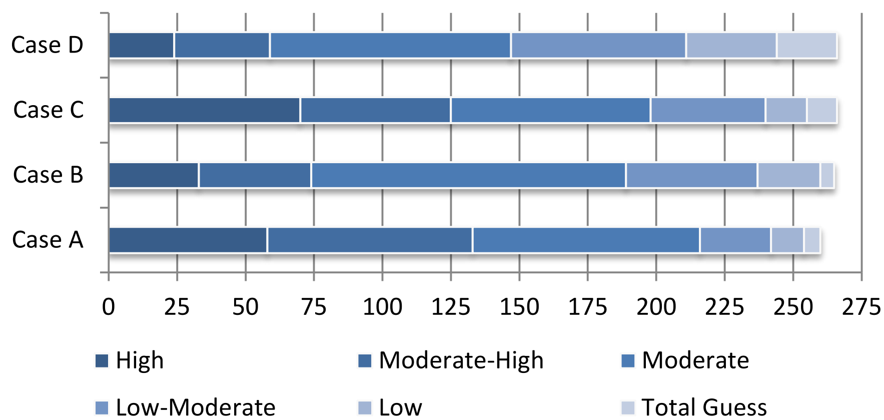

Figure 7. Summary of student reported Confidence level for Cases A through D.

Figures 7 and 8 are bar graphs that show the comparison between the student's Confidence level and Understanding for each case. The Confidence levels are Total Guess, Low, Low-Moderate, Moderate, Moderate-High, and High; the Understanding levels are Weak, Medium, and Strong. Confidence and Understanding levels seem to match the rise and fall of the correct predictions seen in Figures 6.

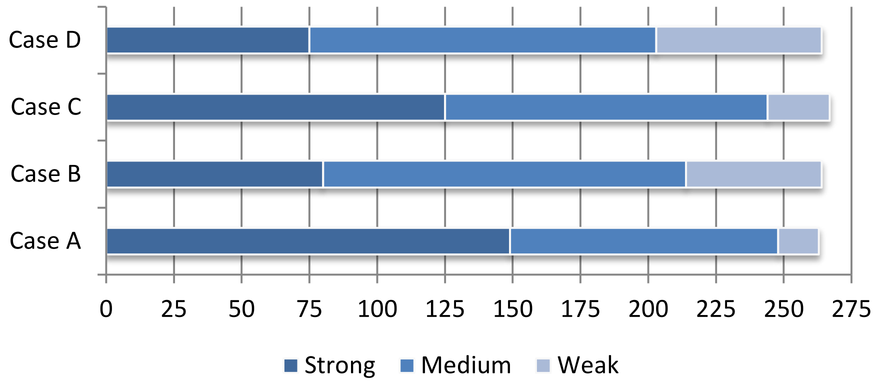

Figure 8. Summary of student reported Understanding for Cases A through D.

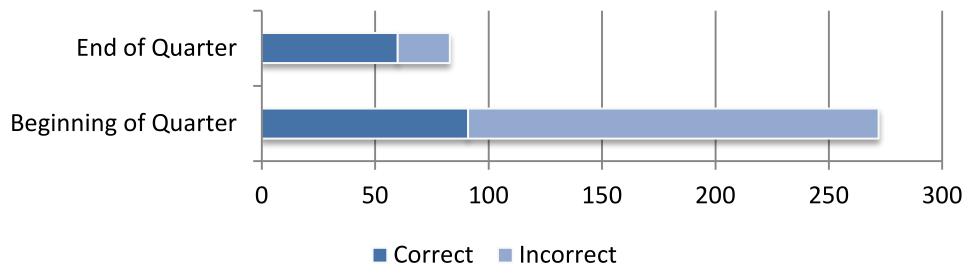

Figure 9. Summary of student reported DCI responses for Question 12.

Figures 9 and 10 are bar graphs that show the comparison between a correct and an incorrect response for Question 12 of the DCI and the student reported Confidence level for each case. The Confidence levels are Total Guess, Low, Low-Moderate, Moderate, Moderate-High, and High. The overall number of students who provided responses for the beginning of the quarter was 272 responses with 83 responses for the end of the quarter, and the percentage of correct responses was 33% for the beginning of the quarter and 72% at the end of the quarter. The overall number of students who provided a Confidence level was 90 responses for the beginning of the quarter and 66 responses for the end of the quarter.

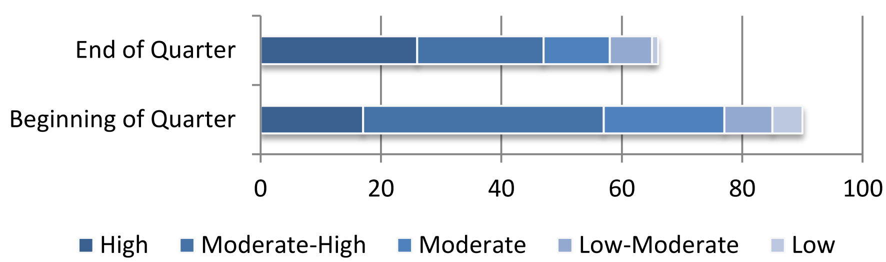

Figure 10. Summary of student reported DCI Confidence level for Question 12.

Table 1 summarizes the distribution of responses for Predictions, Confidence, and Understanding, and Table 2 summarizes the distribution of responses for Question 12 at the beginning and end of the quarter and the Confidence level for this question.

Table 1. Summary of number of student responses for Cases A through D.

Prediction	Case A	Case B	Case C	Case D
Correct	180	69	242	73
Incorrect	89	198	24	194
Total Responses:	269	267	266	267
Confidence	**Case A**	**Case B**	**Case C**	**Case D**
High	58	33	70	24
Moderate-High	75	41	55	35
Moderate	83	115	73	88
Low-Moderate	26	48	42	64
Low	12	23	15	33
Total Guess	6	5	11	22
Total Responses:	260	265	266	266
Understanding	**Case A**	**Case B**	**Case C**	**Case D**
Strong	149	80	125	75
Medium	99	134	119	128
Weak	15	50	23	61
Total Responses:	263	264	267	264

Table 2. Summary of number of responses and Confidence level for Question 12 of the DCI.

Prediction	Beginning of Quarter	End of Quarter
Correct	91	60
Incorrect	181	23
Total Responses:	272	83
Confidence	**Beginning of Quarter**	**End of Quarter**
High	17	26
Moderate-High	40	21
Moderate	20	11
Low-Moderate	8	7
Low	5	1
Total Responses:	90	66

Discussion

Analyzing the data acquired during the Rolling Cylinders IBLA has provided some interesting results. Firstly, the students achieved a greater overall understanding of the targeted concepts explored with the IBLA. This is illustrated by the increase from 33% to almost 75% in correct responses from Question 12 of the Dynamics Concept Inquiry. This is backed by an impressive jump from 19% in the High confidence level at the beginning of the quarter to almost 40% in the High confidence level at the end of the quarter. This leads one to believe that even though the activity was performed in the middle of the quarter, the effect has been lasting. Execution of this activity has helped the students to internalize the concept and with continued reinforcement from homework and exams, their understanding of work-energy and of mass moments of inertia have hopefully improved.

An interesting notion that was discovered while analyzing this data is that confidence appears to be linked to understanding. The rise and fall of the amount of student reported responses in the High Confidence level can be seen in the rise and fall of the quantity of student reported responses in the Strong Understanding level. It seems that the more confidence that a student has, the more apt they are to try and experiment with new ideas, and this helps to promote learning. When a student feels less lost, they are able to apply the mathematical analysis and see the connection to the bigger world now that there is global understanding. This confidence and global understanding shows the student that the mathematical terms are linked to a physical action in the real world; now each mathematical term in the governing equations has more meaning and has its own place in the student's logical train of thought.

Initially it was hoped to show that the student would become more accurate as the activity progressed. Primarily there seemed to be this trend as Case C was the highest reported correct prediction, but this number of correct predictions soon plummeted at Case D. This may be attributed to the student still struggling to transition from parroting what the instructor has explained about how the physical phenomenon behaves to actual internalization of this understanding. Case D may also be strangely unintuitive as it drastically exemplifies the idea that the linear velocity is totally independent of the radius and mass if the objects are of the same shape. Many students predicted that the two PVC pipes would tie at the bottom of the ramp, so they initially understood the idea about the independence of the radii, but many were still hung up on the independence of mass. This case causes cognitive conflict in the students, motivating them to further explore the dynamics to try to understand the underlying principles. Homework problems and after-class discussion can then be used to help explain the results of Case D and this appears to be successful as shown by the DCI results.

Conclusions

The Rolling Cylinders IBLA reinforces the idea of self-efficacy (Bandura, 1994): student confidence is linked to student understanding. Once a student feels confident that they are either on the right track or understand the concept at hand, they are more likely to be accurate in their predictions. This confidence may be attributed to the physical act of experimentation that leads the student to better understanding the principle at hand, namely that the behavior of rolling objects is directly linked to their shape and Mass Moment of Inertia. This activity leads to the internalization of these principles, and the analysis and mathematics required to describe the phenomenon. The principle of learning about the physical phenomenon through performing the experiment yourself and observing the results is in seamless balance with the theory that is taught within the classroom during the lectures.

The hope is that these students will now possess the ability to apply these dynamics principles to more complicated systems. Since the correlation between the mathematical components is solid, they will be better able to distinguish the individual, simpler components and how they will thus interact with the world as a whole. It is hoped that the student is now aware that the translational velocity is linked to the Mass Moment of Inertia and that the concept of Work-Energy allows them to observe the transition of potential energy converting to kinetic energy as the object reaches the datum. An IBLA allows the student to view the physical phenomenon intimately and this leads to better connections between cause and effect. Case E of this activity also allows the students to experiment and "play" with this newfound knowledge and stimulates the learning process. Since the experience was first person and not just visually seen passively as in a presentation or video, the student will now be able to recall the memory of how the system worked, recall the concept of why it was the way it was, and ultimately recall the analysis and math that was used to help describe the action.

The execution of these activities in class follows along with the Mechanical Engineering ABET accreditation criteria of 2015-2016 by "The curriculum must require students to apply principles of engineering, basic science, and mathematics … to model, analyze, design, and realize physical systems, components or processes…" (ABET, 2016) It is important to align the goals of the activities with the ABET criteria so that an overarching body of standards is used to assess the usefulness of this endeavor.

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Note: *Student author

Appendix A. Equipment List

Object	Outer Radius [inch]	Inner Radius [inch]	Mass [lbf]	Length [inch]	Material -	Supplier -
Big Metal Solid Cylinder	1.75	-	2.7	2.90	Aluminum 6061	McMaster Carr 8974K89
Small Metal Solid Cylinder	2.00	-	-	3.00	Aluminum	Metal Supply
Black Metal Pipe	1.75	1.45	2.7	3.15	Steel Unthreaded Pipe Size 3	McMaster Carr 7972K322
Grey Metal Pipe	-	-	-	-	Stainless Steel	Scrap
Big PVC Pipe	6.25	-	-	3.00	PVC	Home Depot
Small PVC Pipe	2.00	-	-	3.00	PVC	Home Depot
Wood Solid Cylinder	2.00	-	-	3.00	Wood	Home Depot

Appendix B1. Individual Prediction Sheet

Black Metal Pipe   Big Metal Solid   Grey Metal Pipe

Big PVC Pipe   Small Metal Solid   Wood Solid Cylinder   Small PVC Pipe

<u>CASE A</u>

Consider the big metal solid cylinder and the black metal pipe. These two have the same radius and mass. Which will roll to the bottom of the ramp first? (Do not discuss with your teammates).

_____big metal solid cylinder **______black metal pipe** **_____same time**

Write a brief explanation of your answer below.
Circle your prediction confidence level below.
Total Guess   Low-Moderate   Moderate   Moderate-High   High

Next, discuss with your team and fill out the team worksheet for Case A only. Do not change your individual prediction when you are discussing as a team.

CASE B

Consider the small metal solid cylinder and the big metal solid cylinder. These two have different radius and mass, but have the same shape. Which will roll to the bottom of the ramp first? (Do not discuss with your teammates).

______ small metal solid cylinder   _______ big metal solid cylinder   ______same time

Write a brief explanation of your answer below.
Circle your prediction confidence level below.
Total Guess   Low-Moderate   Moderate   Moderate-High   High
Next, discuss with your team and fill out the team worksheet for Case B only. Do not change your individual prediction when you are discussing as a team.

CASE C

Consider the small metal solid cylinder and the black metal pipe. These two have a different shape, radius, and mass. Which will roll to the bottom of the ramp first? (Do not discuss with your teammates).

______ small metal solid cylinder   _______ black metal pipe   ______same time

Write a brief explanation of your answer below.
Circle your prediction confidence level below.
Total Guess   Low-Moderate   Moderate   Moderate-High   High
Next, discuss with your team and fill out the team worksheet for Case C only. Do not change your individual prediction when you are discussing as a team.

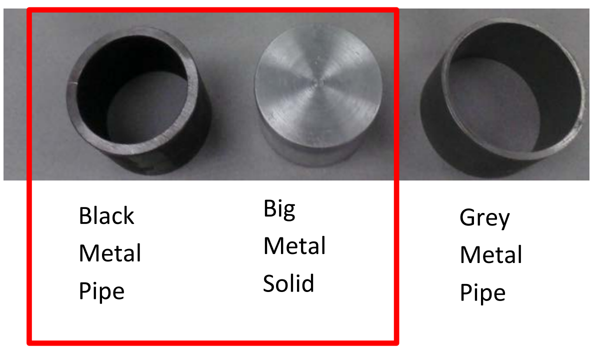
CASE D

Consider the small PVC pipe and big PVC pipe and grey metal pipe. The have the same shape, but a different radius and mass. Which do you predict will roll to the bottom of the ramp first, second, and third place? Indicate with a “1”, “2” and “3”. If you think some will tie, give them the same number. (Do not discuss with your teammates).

_______small PVC pipe **________ big PVC pipe** **_______ grey metal pipe**

Write a brief explanation of your answer below.
Circle your prediction confidence level below.
Total Guess Low-Moderate Moderate Moderate-High High
Next, discuss with your team and finish filling out your team worksheet. Do not change your individual prediction when you are discussing as a team.

<u>Appendix B2. Team Worksheet</u>



CASE 1.
Consider the big metal solid cylinder and the black metal pipe. These have the same radius and mass.

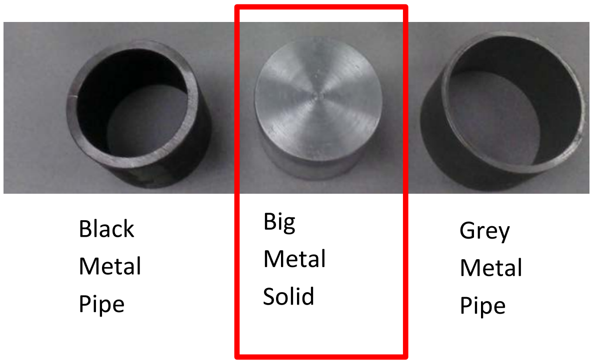
1) Go to Polylearn and open the Quiz (this is not graded!) called “Rolling Activity Individual Predictions” and fill out your answers to Case 1 and click next before continuing.
2) Discuss with your team which object will roll to the bottom of the ramp first.
3) Record # of prediction votes below (it is ok if your vote changes after team discussion).

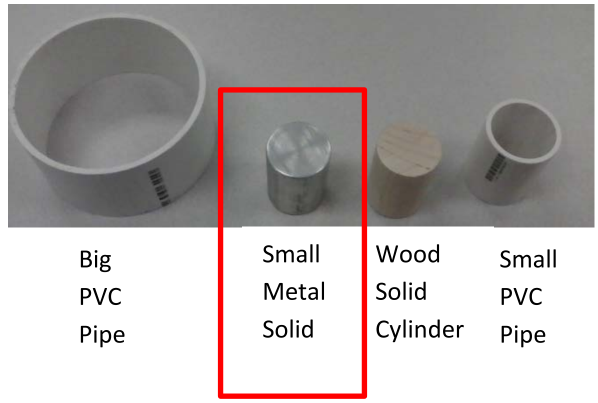
Big metal solid cylinder ____ **Black metal pipe ____** **Same time ____**

Now, go get the Big Metal Solid Cylinder and Black Metal Pipe from the assistants. Place the rolling objects close to the top of the ramp, side by side and held by the starting gate. Have the starting gates as vertical as possible. Flip the starting gate handle as quickly as possible to create a ‘fair’ start. When the objects roll to the bottom of the ramp catch them or use a cushion to stop them so they are not damaged by bouncing on the stone ground. Perform this exercise multiple times, with different objects on each side of the ramp.

Which rolling object reached the bottom of the ramp first?
Explain results using dynamics principles
Circle the object that has the larger mass moment of inertia

solid cylinder *black metal pipe* *the two have the same mass moment of inertia*
Discuss the translational and rotational energy of the cylinder and pipe. Which is object has the larger translational kinetic energy when it reaches the bottom? Which has the larger rotational kinetic energy?





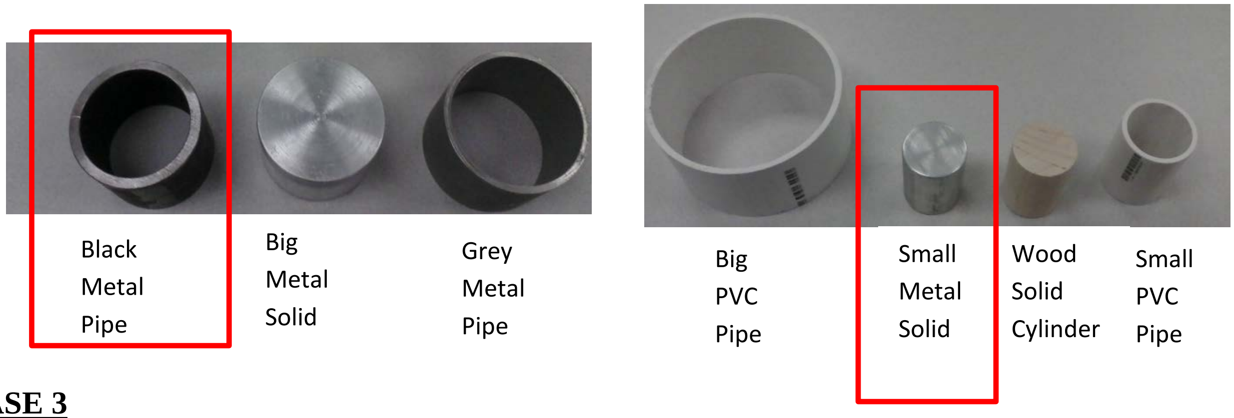
<u>CASE 2</u>
Consider the **small metal solid cylinder** and the **big metal solid cylinder.** These two have different radius and mass, but have the same shape.

1) Return to the Polylearn quiz and individually answer the questions for Case 2 (don't confer with you teammates when answering these questions!). Click next and then continue.
2) Discuss with your team which object will roll to the bottom of the ramp first.
3) Record # of prediction votes below (it is ok if your vote changes after team discussion).

____ small metal solid cylinder ______ big metal solid cylinder ______same time

Now, go get the Small Metal Solid Cylinder and Big metal solid cylinder from the assistants. Place the rolling objects close to the top of the ramp, side by side and held by the starting gate. Have the starting gates as vertical as possible. Flip the starting gate handle as quickly as possible to create a 'fair' start. When the objects roll to the bottom of the ramp catch them or use a cushion to stop them so they are not damaged by bouncing on the stone ground. Perform this exercise multiple times, with different objects on each side of the ramp.

Which rolling object reached the bottom of the ramp first?
What are some of the properties of the two cylinders that are the same?
What properties are different?
Which object has the larger mass moment of inertia, the *big metal solid cylinder* or the *small metal solid cylinder*? (different mass and radius).
Any thoughts on how to explain what you saw in the race?



CASE 3

Consider the small metal solid cylinder and the black metal pipe. These two have a different shape, radius, and mass.

1) Return to the Polylearn quiz and individually answer the questions for Case 3 (don't confer with you teammates when answering these questions!). Click next and then continue.
2) Discuss with your team which object will roll to the bottom of the ramp first.
3) Record # of prediction votes below (it is ok if your vote changes after team discussion).

______ small metal solid cylinder   _______ black metal pipe   ______same time

Now, go get the Small Metal Solid cylinder and black metal pipe from the assistants. Place the rolling objects close to the top of the ramp, side by side and held by the starting gate. Have the starting gates as vertical as possible. Flip the starting gate handle as quickly as possible to create a 'fair' start. When the objects roll to the bottom of the ramp catch them or use a cushion to stop them so they are not damaged by bouncing on the stone ground. Perform this exercise multiple times, with different objects on each side of the ramp.

Which rolling object reached the bottom of the ramp first?
What are some of the properties of the two cylinders that are the same?
What properties are different?
Which has larger Total Kinetic Energy when it reaches the bottom, the *small metal solid cylinder* or the *big metal solid cylinder? (*different mass, different radius*)*

CASE 4

Consider the small PVC pipe and big PVC pipe and grey metal pipe (be sure you are using the gray metal pipe and not the black metal pipe). The have the same shape, but a different radius and mass. What order do you predict they will roll to the bottom of the ramp? Do several trials of the race, and you might need to do some pairwise races as well (a little tough to see the 3-way race sometimes)

1) Return to the Polylearn quiz and individually answer the questions for Case 4 (don't confer with you teammates when answering these questions!). Click next and then continue.

2) Discuss with your team which object will roll to the bottom of the ramp first, second, third or ties.
3) Record # of prediction votes below. (it is ok if your vote changes after team discussion).

_______1) small PVC pipe, 2) big PVC pipe, 3) grey metal pipe
_______1) small PVC pipe, 2) grey metal pipe, 3) big PVC pipe
_______1) grey metal pipe, 2) big PVC pipe, 3) small PVC pipe
_______1) grey metal pipe, 2) small PVC pipe, 3) big PVC pipe
_______1) big PVC pipe, 2) small PVC pipe, 3) grey metal pipe
_______1) big PVC pipe, 2) grey metal pipe, 3) small PVC pipe
_______1) small PVC pipe and big PVC pipe tie, 2) grey metal pipe
_______1) small PVC pipe, 2) big PVC pipe and grey metal pipe tie
_______They all reach the bottom at the same time

Now, go get the small PVC pipe, big PVC pipe and grey metal pipe from the assistants. Place the rolling objects close to the top of the ramp, and perform this exercise multiple times.
Which rolling object reached the bottom of the ramp first? (Rank the order that they reached)

Write the work-energy equation for any rolling object using position one at the top of the ramp and position two at the bottom. Express the mass moment of inertia as $\overline{I} = cmr^2$ where c is a constant that depends on the shape (solid, hollow, thin-walled, etc.). What is the critical variable if you want to predict which object reaches the bottom? Solve your equation for this variable.

Discuss as a team and record # of votes for each of the following questions.

1) All solid cylinders regardless of radius and mass arrive at the bottom at the same time
   True ___ False ____

2) All thin walled pipes regardless of radius and mass arrive at the bottom at the same time
   True ____ False ____

3) Which will arrive first, a thick walled pipe or a thin walled pipe regardless of radius and mass?
   Thick walled____ Thin-walled____ They will arrive at the same time____

CASE 5

We have several other rolling objects as well. Grab 2-3 different objects that you haven't raced yet. Write down what objects you chose and the race results. Does the race match your answers above?

Finally, please answer the remaining survey questions on the Polylearn site so that we can continue to improve this learning experience. Thanks!

Appendix C. Student Predictions, Confidence and Understanding for Cases A through D

Case A: Predictions	
Prediction	**Number**
Big Metal Solid Cylinder	180
Black Metal Pipe	82
Same Time	7
Total Responses:	269
Confidence	**Number**
High	58
Moderate-High	75
Moderate	83
Low-Moderate	26
Low	12
Total Guess	6
Total Responses:	260
Understanding	**Number**
Strong	149
Medium	99
Weak	15
Total Responses:	263

Case B: Predictions	
Prediction	**Number**
Small Metal Solid Cylinder	141
Big Metal Solid Cylinder	57
Same Time	69
Total Responses:	267
Confidence	**Number**
High	33
Moderate-High	41
Moderate	115
Low-Moderate	48
Low	23
Total Guess	5
Total Responses:	265
Understanding	**Number**
Strong	80
Medium	134
Weak	50
Total Responses:	264

Case C: Predictions	
Prediction	**Number**
Small Metal Solid Cylinder	242
Black Metal Pipe	16
Same Time	8
Total Responses:	266
Confidence	**Number**
High	70
Moderate-High	55
Moderate	73
Low-Moderate	42
Low	15
Total Guess	11
Total Responses:	266
Understanding	**Number**
Strong	125
Medium	119
Weak	23
Total Responses:	267

Case D: Predictions	
Prediction	**Number**
1) small PVC pipe, 2) big PVC pipe, 3) grey metal pipe	38
1) small PVC pipe, 2) grey metal pipe, 3) big PVC pipe	28
1) grey metal pipe, 2) big PVC pipe, 3) small PVC pipe	19
1) grey metal pipe, 2) small PVC pipe, 3) big PVC pipe	34
1) big PVC pipe, 2) small PVC pipe, 3) grey metal pipe	3

1) big PVC pipe, 2) grey metal pipe, 3) small PVC pipe	3
1) small PVC pipe and big PVC pipe tie, 2) grey metal pipe	62
1) small PVC pipe, 2) big PVC pipe and grey metal pipe tie	7
They all reach the bottom at the same time	73
Total Responses:	267

Confidence	Number
High	24
Moderate-High	35
Moderate	88
Low-Moderate	64
Low	33
Total Guess	22
Total Responses:	266

Understanding	Number
Strong	75
Medium	128
Weak	61
Total Responses:	264

Dynamics Concept Inquiry Responses

Predictions		Beginning of Quarter	End of Quarter
A and B will have the same speed.		106	8
The speed of A will be greater than that of B.		64	14
The speed of B will be greater than that of A.		91	60
Knowledge of the friction forces is required to answer the question.		7	1
Knowledge of the shape of the cross-section of the thin hoop is required to answer the question.		4	0
Total Responses:		272	83
Confidence		**Beginning of Quarter**	**End of Quarter**
High	5	17	26
Moderate-High	4	40	21
Moderate	3	20	11
Low-Moderate	2	8	7
Low	1	5	1
Total Responses:		90	66

The Teaching Dead: The Introduction of Physical Prototyping in Junior Year Biomedical Engineering

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Abstract

For the past 30 years, the Biomedical Engineering program at Arizona State University has featured senior Capstone courses that require students to design a medical device. This process involves both design and development with understanding the FDA regulatory pathway. Currently there is a hole in our curriculum; there is no formal course focused on prototyping. To address the topics seniors have been deficient in, the BME program at ASU has adopted the "Design Spine". This is a series of courses, which guides the student through design development and ultimately culminates in Capstone. Our desire to expose the students to more prototyping has resulted in the addition of a hands-on, game/entrepreneurial learning based prototyping course that is introduced junior year. This course, BME 382, uses a surrogate product for a medical device to emphasize the actual process of prototyping. The surrogate product used for teaching this course is a board game, as games are very easy to understand compared to medical devices. The BME 382 course begins with a ten question survey and a fifteen minute design challenge given to students (after IRB approval) before the first class. The survey established a baseline for the study of the students' knowledge in design and prototyping, while the design challenge asks the student to apply their knowledge of design and prototyping. During the course of the semester Design Tasks are assigned to students. Design Tasks a mix of individual and team assignments assigned every other week to ensure progress towards a beta/gamma product. A balanced lecture that includes demos, hands-on teaching, and continued development of the prototype represent the majority of the class. At the end of the course, students are given a final which is nothing more than a five minute presentation of the gamma version of the game created by the team and presented to industry experts. Judges rate the gamma prototype based on instructor guided rankings. The class is concluded with a similar 10 question post-course survey and subsequent design challenge to gauge learning. The surveys established that few students had any experience in manufacturing, construction, or design, and even fewer had experience in prototyping. The pre-course design challenge resulted in unorganized ideas. Various students utilized state of the art techniques even though the challenge asked them to develop "something new". The results from the post-course survey and design challenge showed that students benefited from a clear formulated design and prototyping course. This new method of delivering prototyping through a hands-on, game/entrepreneurial based learning course is great at preparing students for their Capstone experience, the workplace, or graduate school. A confidence in the engineering design and FDA regulated medical devices has been established using the surrogate of board game design and manufacturing.

Introduction

There are many forms of pedagogic strategies for teaching material in a number of courses. This paper examines the results from a pilot group of students in a biomedical engineering (BME) course. The purpose is to introduce the topic of physical prototyping to juniors before they begin their senior design project. There are three primary purposes to exposing students to a yearlong senior design process. In order to teach fundamentals of engineering design and design techniques students obtain 1) tools which they can employ from their education, 2) students are able to see a 'bigger picture' in their field of engineering, 3) develop methods of attacking open-minded problems. As such, students typically begin design courses towards the end of their degree. From Carr et al, we can see that prototyping is considered to be one of the top ten design standards and students who improve their skill sets from receiving more hands on learning can vastly benefit from learning prototyping earlier in their engineering education (Carr, 2012). Students who have engaged early and consistently with BME faculty from the beginning of their degree are easily motivated to learn design through the use of prototyping (Bodnar, 2016; Bøhn, 1997; Dutson, 1997; Daly, 2012; Daly, 2012). From day one, it is important to incorporate the design method into the curriculum through lectures and extracurricular activities. This will help better prepare BME students in becoming familiar with the field they are entering, as well as knowing what the BME industry expects. We expanded upon this in our curriculum by moving more technical content, down to the earlier years and dubbed it the Design Spine, Figure 1.

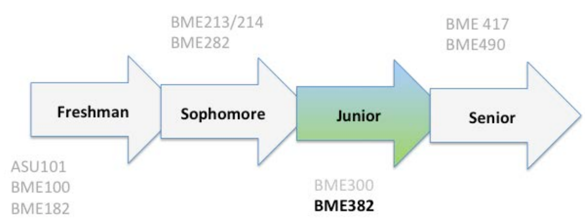

Figure 1. The Design Spine with BME 382 emphasized.

The Design Spine is a set number of classes, which incorporate aspects of fundamentals of engineering design in BME. The courses in the Design Spine are: Intro to Design (182), FDA Regulatory Practices (213), Bioethics (214), Computational Design (282), and Intermediate Design Practices (382). The course BME 382 is special in that it offers the first introduction to physical prototyping. Prototyping in engineering courses is a key aspect in design. Prototyping has been shown to enhance the undergraduate engineering education of third year students and seniors (utilizing rapid prototyping to enhance undergraduate engineering education). In addition, there has been a push into utilizing rapid prototyping methods in BME. The purpose behind this push has been to add an additional and beneficial component into product development. The benefit of prototyping in BME is that it allows students to generate and evaluate ideas while being able to better conceptualize the problem or device being built but to also learn more about manufacturing. In addition, it is even more important that students in BME apply their prototyping to interacting with biological systems and consider this additional design constraint.

The most similar style of learning to BME 382 is entrepreneurial style learning. This involves students working together as teams and learning from their failures, as well as doing tasks that include applying critical and creative thinking to difficult problems. These challenges are not only seen in Capstone design, but in many jobs students may acquire after graduation (Fry, 2012; Banes, 2013; Hain, 2011). Participating in these courses will allow students to be more prepared after experiencing and improving these skills first hand. BME 382 fuses elements of game based learning into entrepreneurial style learning. This encourages students to learn the steps of the design process and stay interested and engaged in the material of the class without giving them a false sense of the process (Fry, 2012). The implementation of the game based learning allows the class to give immediate feedback on the learning by looking at and playing their game as well as encouraging them with the prospect of making a physical copy of their game they can play.

Materials and Methods

Participants. The pool of students came from the pilot course taught in the spring of 2014 on Friday mornings from 9am-12pm. Students met once a week for a the 1 credit, 3 hour a week course. The total number of students enrolled was 40. Each student was given a qualitative survey and a quantitative challenge; pre- and post-course, reference Appendix 1-2. This study was conducted with IRB approval STUDY00000376.

Materials. The main objective of the course had the students develop a gamma prototype of a board game centered on zombies. Figure 2 shows how the board game is similar in regulatory processes to a medical device. The ZoBME board game method is a means to convey and illustrate a bigger picture once students begin their Capstone design yearlong project. The survey was generated using Survey Monkey where students were able to take the survey online. The design challenge was given to students during class. Two programs were used to perform the analysis. Excel was used to compile all the results from the student responses and Statistical Package for the Social Sciences (SPSS) was used to analyze the results.

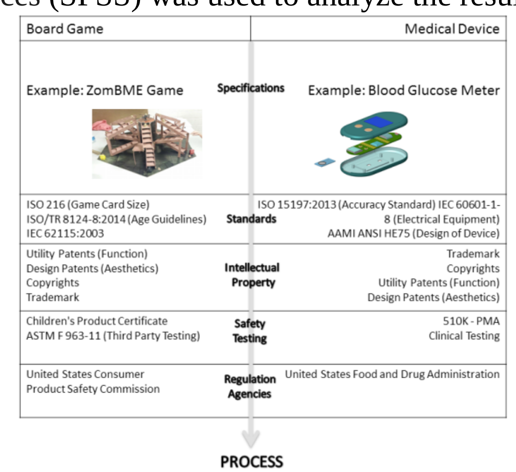

Figure 2. The left column illustrates the board game process and the right column illustrates the medical device process. A Glucose meter is used for the example of the medical device and ZoBME board game is used for the example of the board game.

Testing Material/ Statistical Analysis. The total number of student responses that were paired and analyzed during the spring of 2014 for the BME Prototype survey was 40. The physical prototyping survey (PSS) is a 10-question qualitative survey. The survey was assessed for innovation, prototyping strategies, design and design process. The survey is a 5-point scale. All students enrolled in BME 382 during the spring of 2014 had the opportunity to take the survey. All students were asked to create and use the same anonymous identifier on each instrument.

The total number of students that participated in the spring of 2014 Prototype Design Challenge (PDC) was 37. The PDC is in the form of a question where students are given a problem topic and asked to develop a potential solution. Students completed the PDC once at the beginning of the course and once at the end of the course. The PDC was assessed for innovation, prototyping strategies, and design and design process. The PDC was scored with a double blind standard. The evaluators did not know if they were grading pre- vs. post-course design challenge. All students enrolled in BME 382 during spring of 2014 had the opportunity to take the design challenge. In order to look and find statistical success a Kruskal-Wallis test for non-parametric rank data was completed for PDS. Paired students t-test results of PDS looked at statistical significance in the three categories of innovation, prototyping strategies, and design and design process.

External Validators. At the end of the course, students were asked to showcase and present the final prototype they have built. Experts in the field from which the prototype came from were asked to come and listen to a five-minute 'elevator pitch' of the prototype. The groups of students presenting the prototype were graded by the experts on a 10-point scale; please see Appendix 3. The grade sheet consisted of 10 subject matters that were grouped into three topics, innovation, prototyping strategies, and design and design process.

Results

The following graphs show the results from the qualitative survey and the quantitative design challenge in terms of innovation, prototyping strategies, and design and design process knowledge. Figures 3 and 4 show the pre- and post-course differences that show the growth of the students over the past semester in order to see if BME 382 has an effect on these three categories. Figure 5 is a graph that shows the overall learning from the beginning to the end of the semester using both the qualitative and quantitative data using a weighted mean in order to better see the separation from the pre- and post-course in terms of frequency of ratings in the three categories. In this section we will point out the points we find most interesting with the data and we will discuss these points and what this means about the class in the discussion section.

Qualitative Survey. Figure 3 shows analysis of the qualitative survey that students were asked to take and rate themselves and their knowledge on different tasks. 37 students took the pre-course survey and after the course the same 37 students took the post-course survey. You can see the improvement from pre- to post-course results. Looking at the differences between the three there seems to be a smaller increase in innovation after the semester compared to the other two categories. The prototype process though seems to have the largest difference between pre-responses and post-course responses. A quick point to notice is that most of the students believed that they had mastered the three categories. The prototyping process increases almost two points and the design process increase over a point and the innovation increased less than a point.

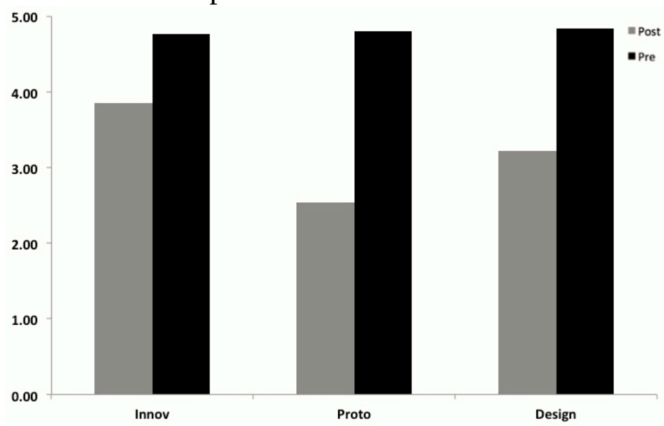

Figure 3. Statistical Analysis of Qualitative Survey: These analysis shows the differences between the pre- and post-course innovation, prototyping, and design process. The pre-course results are in light gray and the post-course are in dark gray.

Quantitative Design Challenge. Figure 4 shows the pre- and post-course results for the design challenge with the same 37 students that took the course surveys. These design challenges were graded based upon a rubric so that all of the challenges were graded based upon the same criteria. You can see that as above in the survey results the innovation had the smallest increase of the three categories. Unlike the survey results though the biggest increase is in the design process rather than the prototyping process. For the prototyping process and the design process there was an increase of over 1 point in a 5 point scale whereas the innovation made an increase of slightly less than 1 point. With the design and the prototyping being the focus of the class it is promising to see the largest improvement in these categories.

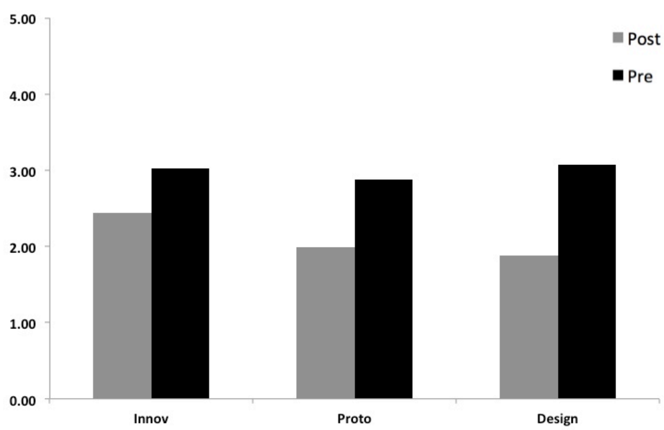

Figure 4. Statistical Analysis of Quantitative Design Challenge: These analysis show that there was a difference between the pre- and post-course design challenge. The pre-course results are in light gray and the post-course results are in dark gray.

Weighted mean analysis of results. Figure 5 shows the weighted means for the results that we see in all of the three categories using the results from the design challenge. From looking at the results we can see that there were a lot of changes in all three categories with the 1 ratings drastically decreasing and either moving to ratings of 2 or 3. There is a shift of the lower ratings to the higher ones that are very obvious from looking at the 1 ratings but are observant in the higher 4 and 5 ratings as well. The design and the prototyping categories has a large amount of people who had a low baseline level of understanding move to the middle ratings and many people also shifting to higher categories showing a great understanding of the design and prototyping processes that are taught in the class.

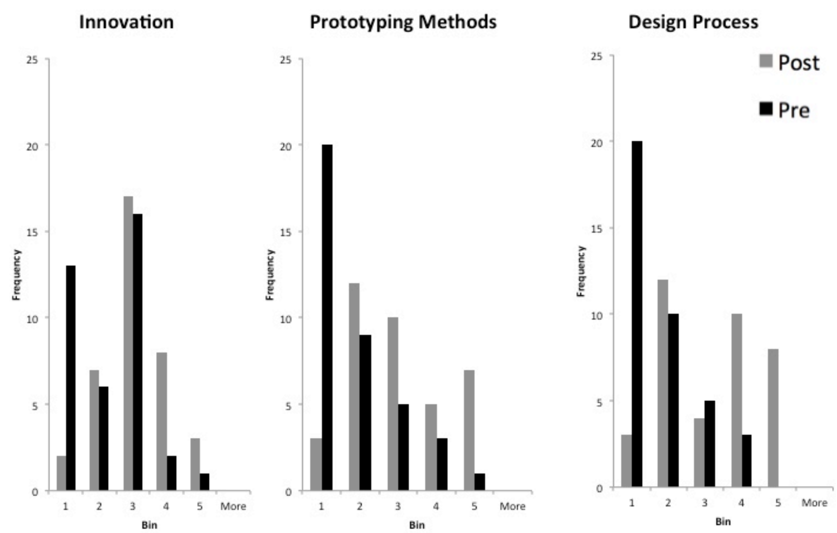

Figure 5. This figure shows that there was a change in learning according to the pre- (dark gray) and post-course (light gray) between the three groups of Innovation, Prototyping Strategies, and Design and Design Process using a weighted mean.

Discussion and Conclusion

This study looked at the improvement in innovation, prototyping methods, and design process of 37 Biomedical engineering students taking BME 382 (biomedical product design). The results from the qualitative survey and the quantitative design challenge show there is a large improvement in all three categories after the semester. With these results we will continue to improve the course and the other design spine courses to continue to increase the ratings of the design process, prototyping methods and try to improve innovation indirectly.

The results from the pre-course survey show that the students on average thought that their innovation was rated pretty high, around a 3.75. However, when we looked at the design challenge to determine how they actually performed, their innovation was lacking and was around a 2.25, over a point different. After the course the students felt that their innovation improved by almost a point and the design survey showed that they had improved, but not by that amount. Looking at the weighted mean from the innovation we can see the frequency of the different ratings. We see a large increase of the higher ratings and a drastic decrease of a 1 rating. This shows a great baseline improvement of innovation from pre- to post-course. The results for the pre-course survey for the prototyping methods show that many of the students did not understand or haven't used the prototyping tools they have available to them in their major. On average, they gave themselves a rating around a 2.5. Similar to the innovation, there is a difference when looking at the design challenge of where they overestimated where they think they are at in terms of prototyping. The students obtained a rating around 1.8 which is smaller than the 2.5 they put themselves at. Looking at the post-course survey and the design challenge we see that they had an extreme increase in where they think they are in terms of prototyping with an increase of about 2 points. The design challenge showed an increase of around 1.2 point, which is still a large increase in understanding for a 3 hour a week class. This is the biggest category that we wanted to address with the class. The goals of the class is to get the students to understand the prototyping tools and get a hand on experience with them so they will have an increased understanding going into Capstone and eventually their careers as biomedical engineers. Looking at the weighted mean results we see that the experience from the course evened out the large spike we were seeing in the 1 and 2 area and move people up to the middle and high ratings.

Looking at the final category for design process we see around the same results as we did from the innovation and the prototyping with a higher rating of a 3.2 for the pre-course survey compared to the pre-course design challenge rating of a 1.75. There was also a large increase in what the students think their rating was post-course and what was seen with the design challenge. There was about a 1.5 point increase of the survey, though unlike the other categories they were pretty accurate of their improvement with the increase of the design challenge being around 1.5 points as well. Looking at the weighted mean results we see a lot more students move to the higher ratings compared to the other categories which explains the larger improvement compared to the other categories. Similar to the prototyping process, the design methods were also a focus in the course where we focused on the mechanics of a board game in the same manner an engineer would focus on the function and specifications of a product and how both of these aspects would meet customer needs.

In conclusion we believe that this first class of students has really shown improvements after going through the course in all three of the categories. More specifically, we are excited to see the improvement in the design and prototyping categories, which is the main focus of the course. In the future there will be improvements to the course to try to make the increase in improvement of knowledge in the categories larger than was shown in this data. Other factors will also be considered such as class size, time and day placement of class, and the effect of a different professor teaching the course. Future work will include the other factors that may affect these results as well as changing many aspects of the course to see what activities have a larger impact on the different categories. We will also add a quality component to the class to help prepare the students for the Capstone course and eventually quality careers in the future.

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Appendix

1. Prototype Survey

BME 382 Pre-course Survey
(on a scale of 1 – strongly disagree; 2- disagree; 3 – don't know, not applicable; 4 – agree; 5 strongly agree) please answer the following questions:

1. I know the medical device design pathway.
   ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
2. I understand how to prototype (paper or CAD) projects.
   ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
3. I understand how to fabricate.
   ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
4. I understand graphics software(s) such as: (Solidworks, CAD, Photoshop or other).
   ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
5. I understand how to write product labels and instructions.
   ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
6. I can perform laser cut, 3D printing or scanning.
   ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
7. Team work supports learning.
   ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
8. I like working in teams
   ○ 1 ○ 2 ○ 3 ○ 4 ○ 5

BME Post-course Survey
(on a scale of 1 – strongly disagree; 2- disagree; 3 – don't know, not applicable; 4 – agree; 5 strongly agree) please answer the following questions:

1. The goals of the course were clearly defined
   ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
2. The topics covered were relevant to the course
   ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
3. The training experience will be useful in my career or future educational plans.
   ○ 1 ○ 2 ○ 3 ○ 4 ○ 5

4. I understand how to design and build a medical device
   ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
5. I understand how prototyping fits into device design
   ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
6. The lectures were useful and relevant to device design
   ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
7. The hands on experience learning supported my understanding.
   ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
8. I worked well with my group
   ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
9. I found the course work easy compared to other courses
   ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
10. I put more than 3 hours a week into this course
   ○ 1 ○ 2 ○ 3 ○ 4 ○ 5

2. Design Challenge

BME 382 student outcomes, effectiveness and improvement study

NOTES: *You will be given extra credit points upon completion of BME 382 irrespective of your design and performance on this challenge. If you have any questions concerning the research study, please contact the research team at: JEFFREY.LABELLE@asu.edu, (480) 727-9061. If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788. Filling out the survey will be considered your consent to participate.*

Design Challenge: *There is a need to create a device, which can detect small concentrations of an infectious disease, such as Methicillin Resistant Staphylococcus aureus (MRSA) in a patient sample. You will have 30 minutes to design such a device. Include a description of the device and a pencil and paper design (sketch). The design should include considerations such as obtaining patient samples, performing sample purification and concentration, detection method, a friendly user interface, costs, etc.*

Infectious disease bacteria information: bacteria can range in morphology or shape (rod, cone, sphere, etc); size (4.5 um and less); Catalase positive or negative (formation of bubbles when place in hydrogen peroxide); Gram positive or negative (uptake of Gram staining dye); motility, site of infection; etc. These data are used by clinicians to determine what bacterial infection their patient has and have been used for over 130 years.

Innovation: 5 points,

- 1 pt: Exactly the same, or very similar to a well-known product used in the medical field
- 2pts: Exactly the same, or very similar to a product extensively researched
- 3pts: Similar to something that already exists, but has smaller differences
- 4pts: Might resemble something that already exists, but has major differences
- 5pts: A completely new idea- patentable!

Prototyping strategies: 5 points,

Components: Diagram (alpha), flow chart, brainstorming, prototyping creation process explanation

- 1 pt: There is no diagram/alpha/chart, but it is somewhat explained
- 2pts: There is some kind of diagram/alpha/chart, but is it not labeled or explained
- 3pts: There is some kind of diagram/alpha/chart, but is it not labeled or explained that well
- 4pts: There is a diagram/alpha/chart, and it is labeled/explained, but there is not information about how it will be created (in terms of alpha/beta/gamma)
- 5pts: There is a diagram/alpha/chart, it is labeled/explained, and there is information about how it will be created (in terms of alpha/beta/gamma)

Design/design process: 5 points, Components: Specifications, explanation about the manufacturing process, testing methods, need, compare to SOTA, how to validate or verify • 1 pt: There are at least 2 of the above components • 2pts: There are 2- 4 of the above • 3pts: There are 2-4 of the above and at least 2 are explained • 4pts: There are at least 3 of the above, and 3 are explained • 5pts: 4+ and all described

3. *External Validators Grade Sheet*

What is the genre and targeted population of the game?
What is the potential market size for the game?
Did the company plan ahead for success and future growth?
What are the manufacturing costs for the game? How do these costs compare to market averages?
What percentages of these costs are focused on the pieces, board, and labor? Do the costs adequately reflect the quality of the game?
What is the manufacturer suggested retail price (MSRP)? Is this price appropriate for the targeted consumer? Below/above price range?
How easy are the instructions to comprehend? How long are they and is there complicated language? If the targeted consumer is very young or very old, will they need frequent assistance in understanding how to play the game?
On average, how many hours of game play can the consumer expect? Is it likely to hold their interest throughout this duration, or will they quickly become board?
What is the minimum, average, and maximum number of players who can play this game at one time?
Is the game content (pieces, story, duration) appropriate for the targeted audience? Has the company given thought to industry standards and taken steps to properly regulate themselves?

Engaging Undergraduate Students in Nano-Scale Spin-Electronics Research through Summer Internship

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Abstract
Spin Transfer Torque Magnetic Memory (STTRAM) is a promising technology for non-volatile information storage. In this technology the information is stored in magnetic form that is non-volatile and also much more scalable as compared to the existing charge-based storage technologies such as SRAM, DRAM, and flash. Moreover this technology is compatible with the standard CMOS technology, which is the mainstream technology for digital integrated circuits. Spin Transfer Torque refers to the mechanism by which the state of a Magnetic Tunnel Junction (MTJ) device is changed in a write operation. The main target application of STTRAM is for storage and the main targeted market is replacement of DRAM main memory and SRAM cache. In this research, we investigate a unique application for STTRAM and that is to realize reconfigurable logic using Look-Up Table (LUT) based logic implementation in which the LUTs are implemented using STTRAM technology on top of a CMOS transistor fabric. Implementing part of a logic circuit in a programmable form offers opportunities for power and performance improvements via dynamic hardware reconfiguration. Research experiences on such advanced technologies are far from reach in undergraduate level studies. In this paper, we present an approach to address this gap via summer research opportunities for undergraduate students. The internship is planned over 10 weeks, and the student interns are assigned a graduate student mentor and a faculty advisor. This paper presents the details of the project, research and educational objectives, results obtained, and the student surveys assessing the outcomes.

Introduction
The main idea of this project was to bring the experience of research on cutting-edge nano-scale electronics technologies to undergraduate students and inspire them to pursue higher education and research careers. Research experiences are not readily available in the traditional undergraduate curriculum, especially for community college students. An effective method to address this gap is to offer summer research experience for undergraduate students. An effective research experience for undergraduate students requires proper definition of a focused research problem, proper training and mentoring. Through a collaboration between a community college focused on education and a 4-year higher education institution offering research opportunities, we havee been able to host four undergraduate students from the community college in our research laboratory in the 4-year university. The undergraduate student research interns were paired and mentored by a master student who was experienced in the assigned research topic. A dedicated faculty member was in charge of defining and supervising the research tasks.

The research internship was conducted for 10 weeks during summer. The undergraduate student interns had weekly meetings with their mentor and faculty advisor. The assigned research task was to explore design optimizations for a spin-electronics based logic circuit technology for reducing power consumption and improving performance. The students were given orientation and resource to learn the basics of the spin-based electronics nanotechnology under investigation. They were also given tutorials to learn the modeling and simulation environment. They were tasked to collect power and performance results of a design by varying a technology parameter called Tunneling Magneto Resistance (TMR). They were then asked to interpret the results and offer meaningful conclusions as to proper optimization of the TMR. Then they were tasked to do a literature survey and see if the TMR values that they are recommending are feasible to manufacture. Based on their survey results, they made a final conclusion as to what TMR values can be reasonably targeted for optimal spin-electronics logic circuit design, while meeting the manufacturing limitations.

The students made midterm and final project progress report in both written and oral presentation forms to practice their wring as well as oral presentation skills. The students were surveyed on the effectiveness and satisfaction of their research experience before exiting the program. This paper shares the research project details, research results, and the student survey results.

Research Project Background

An emerging nano-scale technology that has the potential to transform the computing and information storage is the Spin-Transfer Torque Random-Access Memory (STT-RAM). The RAM is a data storage device that can be volatile or nonvolatile. If the RAM is volatile, it can store digital data as long as the power is on. Once the power is off, the stored information is lost. The existing commercial semiconductor based non-voltage memory technology is the flash technology that is still charge based. It relies on trapped charge on a floating gate node. The limitation of the charge-based storage technologies is scalability as the dimensions are scaled to nano-scale; the amount of charge representing the information is also scaled down, posing reliability and retention time limitations. Researchers have developed a new technology for non-volatile storage called STTRAM that is non-charge based and rather magnetic based. MRAM, which stands for magnetoresistive random-access memory, is the original name of this new technology[1].

Spin Transfer Torque (STT) is an effect in which the orientation of a magnetic layer in a Magnetic Tunnel Junction (MTJ) or spin valve can be modified using a spin-polarized current. STT-RAM is non-volatile, that is, it can retain or store information even if the power is off. This recent technology can store data in the form of magnetic orientation, and hence offers better scalability than the existing charge-based storage technologies. It has certain advantages that can offer such as low power consumption, low current requirements, non-volatility, ease of programing, scalability, and standard CMOS compatibility[2].

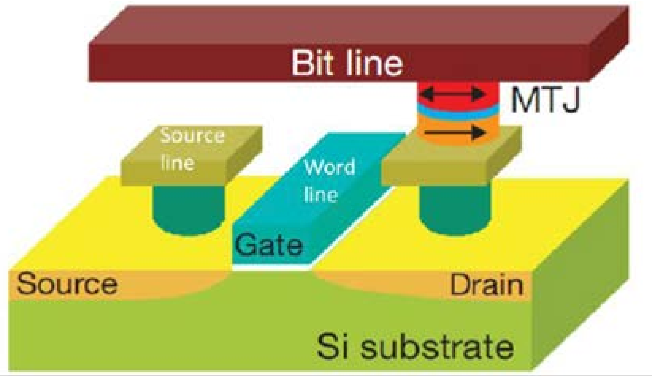

Figure 1. Basic structure of an STT-RAM cell[3], composed of one transistor and of MTJ

A memory such as STT-RAM is built from a grid of cells, as shown in Fig. 1, one cell of STT-RAM consists of two components: one magnetic tunnel junction and NMOS transistor[4]. The magnetic tunnel junction consists of two ferromagnetic layers (one free and the other fixed) separated by a thin insulator. For the free ferromagnetic layer, the direction of magnetization can be modified, whereas the direction of magnetization is invariable for the fixed ferromagnetic layer. In a magnetic tunnel junction, an effect called tunnel magnetoresistance (TMR) can occur. This effect is a change of value of the electrical resistance of the material that results when an induced magnetic field is applied to the free ferromagnetic layer to modify its magnetic orientation. If the magnetization directions of the free and fixed ferromagnetic layers are parallel or antiparallel, then the electrical resistance of the material changes to a low value (RL) or a high value (RH) respectively. The degree of change in resistance called Tunneling Magneto Resistance (TMR) can be mathematically described in Eq. (1).

$$\mathrm{TMR} = \frac{R_H - R_L}{R_L} \times 100 \ \% \qquad (1)^4$$

A Look Up Table (LUT) is a small memory used for building a programmable logic circuit. The combination of CMOS transistors and MTJs allows for fabrication a Spin Transfer Torque based Lookup Table (STT-LUT). The reconfigurable STT-LUT circuit's main application is to recreate any type of logic based circuit. The main advantage of using this type of circuit is its reprogramming ability. Fig. 2 illustrates the design of a 2-input STT-LUT[4] that contains four MTJ cells storing four binary states. The inputs (A and B) select a unique MTJ to be read out and affect the state of the output (Z). This is a dynamic circuit in which the operation is synchronized using a pulsing clock signal (CLK).

The purpose of this research is to improve the relationship between delay and power of the STT-LUT circuit design[6,7], with respect to TMR values of MTJs also to optimize TMR to improve overall performance of the circuit and finally make recommendations for desired TMR from the MTJ device.

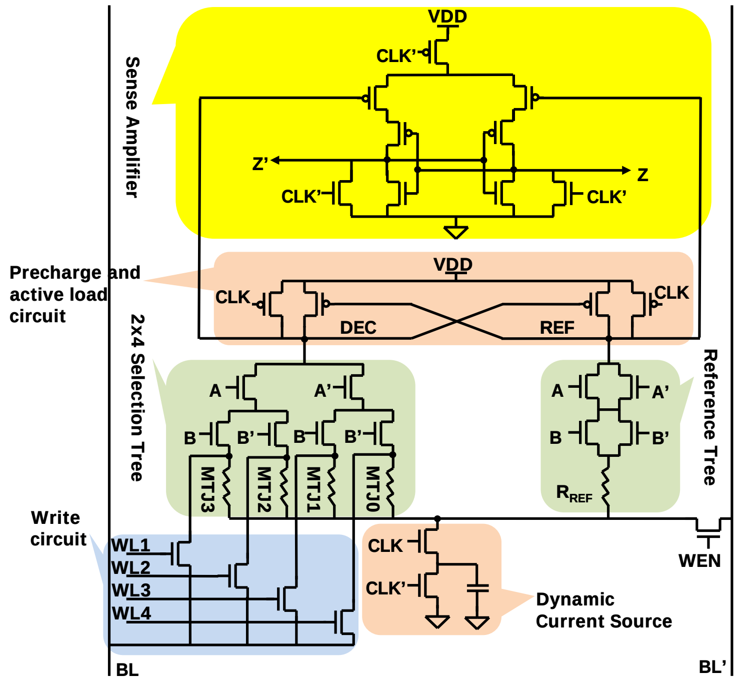

Figure 2. Diagram of 2-input (A, B) Look Up Table with four STT MTJ cells[4]

Approach

In order to fulfill the purpose of this research it is essential to simulate the Spin Transfer Torque Lookup Table (STT-LUT) circuit. A circuit simulator, called Hspice, was used to explore the effects of TMR on circuit power and performance. As previously mentioned TMR depends on two variables, high and low resistances of MTJ. To vary the values of TMR using Hspice, the low resistance (RL) was set constant and the high resistance (RH) was gradually increased, to increase the values of the TMR. Fig. 3, shows simulation waveforms of an STT-LUT programmed to be a NAND gate. The waveforms also illustrated the delay measurement which is defined as the signal propagation delay form clock signal to the outputs (Z).

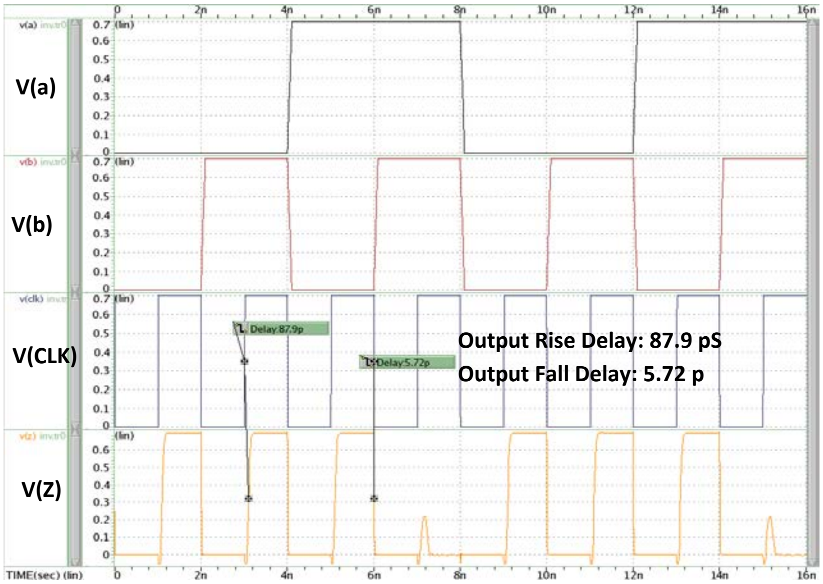

Figure 3. Waveform of STT-LUT type NAND Gate simulated by Hspice tool

The Hspice simulation result of power and delay of the STT-LUT by keeping RL at 6KΩ and sweeping RH from 12KΩ to 45.9KΩ is shown in Table 1. By sweeping RH in this range, the the TMR varied from 100% to 700%. From the results of the Hspice simulations, an optimal pair of resistors was to be selected and used to find a reference resistor. The optimal pair of resistors has to give the lowest values of Power, Delay and Power Delay Product (PDP). The STT-LUT circuit needs to compare the values of MTJ resistance with a reference resistor (R_{REF} in Fig. 2) in order to give a proper output. Through previous research, it was found that if the reference resistor is changed from the average of the high and low resistance resistor to a lower value, the circuit would exhibit lower delay, power and PDP[8]. To find the most optimal value of the reference resistor, we did another sweep of values for the reference resistor.

Table 1. Sample Table of Power, Delay and PDP with calculated TMR values using RL at 6K and RH from 12K to 45.9K ohms.

RH (ohms)	RL (ohms)	Reference resistor (ohms)	TMR	Power (nW)	Delay (ps)	PDP
12000	6000	9000	100	412.4072	161.006	66400.03364
12300	6000	9150	105	411.6145	158.103	65077.48729
12600	6000	9300	110	411.5279	155.4795	63984.15213
12900	6000	9450	115	410.1614	153.0735	62784.84106
13200	6000	9600	120	409.7051	150.5187	61668.27904
13500	6000	9750	125	410.0918	148.243	60793.23871
13800	6000	9900	130	408.6566	146.2943	59784.13124
14100	6000	10050	135	407.5279	144.5547	58910.07333
14400	6000	10200	140	408.2303	143.0409	58393.62952

...	6000	...	...	...	...	...
36000	6000	21000	500	394.7946	118.9823	46973.56954
42000	6000	24000	600	393.5056	118.4537	46612.19429
45000	6000	25500	650	392.599	118.4345	46497.26627
45600	6000	25800	660	392.488	118.4323	46483.25656
45900	6000	25950	665	392.3113	118.4811	46481.47437

Results

Upon completing the necessary simulations under Hspice software, plots were made to observe how increasing TMR values affect the overall power and delay of the circuit. Fig. 4, shows a summary of the power dissipated in the circuit as a function of increasing TMR for constant low resistance values ranging from 1 kΩ to 7 kΩ. As TMR increases, the overall power consumed by the circuit decreases. This can be explained by Ohm's law on the MTJ:

$$I = \frac{V_{MTJ}}{R} \qquad (2)^8$$

Observing Eq. (2), the current of the MTJ is inversely proportional to its resistance; as the resistance of the MTJ increases, the current flowing through the MTJ decreases.

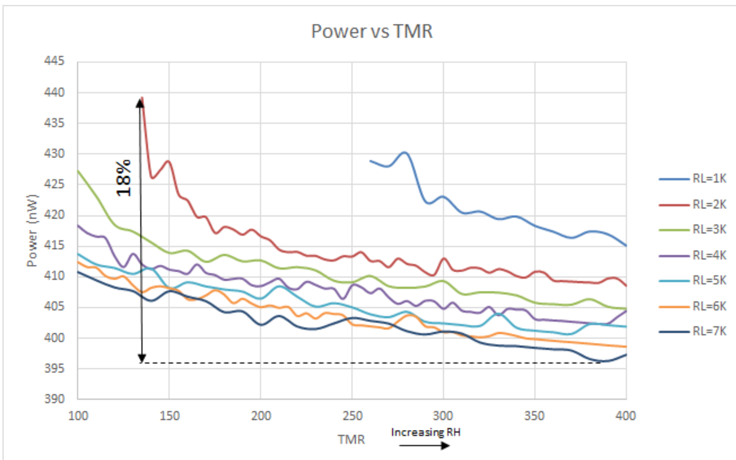

Figure 4. Observing power dissipated in the circuit as a function of increasing TMR for various constant low resistances (RL)

The power dissipation can be modeled as:

$$P = V_{supply}\, I \qquad (3)^8$$

The power dissipation is proportional to the current as well as the supply voltage. Since the supply voltage is at a fixed value (0.7 Volts) the power will be directly proportional to the current. As a result, as the current decreases by increasing TMR, the power also decreases.

Fig. 5 shows the delay of the circuit as a function of increasing TMR for constant low resistance values ranging from 1 kΩ to 7 kΩ. As the TMR increases, the delay decreases but reaches a saturation point because the voltage differential caused by the difference between the MTJ and reference reinstate saturates, as it is limited by the supply voltage.

Fig. 6 shows the power delay product (PDP) of the circuit as a function of increasing TMR for constant low resistance values ranging from 1kΩ to 7 kΩ. Similarly to delay, as TMR increases the power delay product decreases until it reaches the saturation point. Based on these results, we reached the conclusion that it would be best to have a TMR at the highest possible value, which results in lowest possible power and delay. However, there are limitations in the MTJ manufacturing processes that might limit how high of TMR can be achieved.

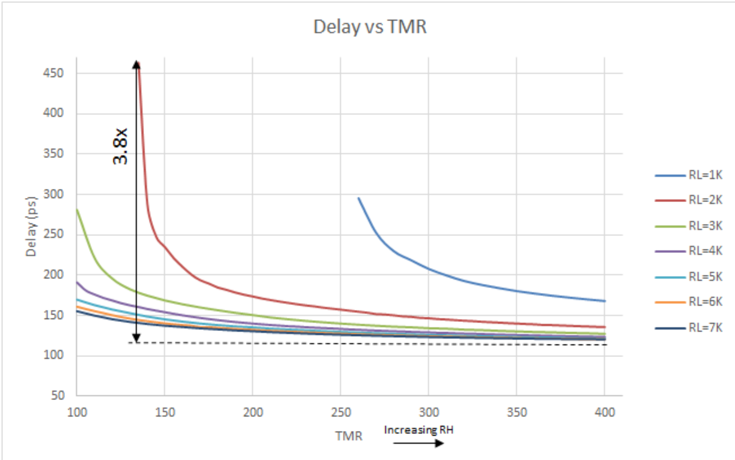

Figure 5. Observing the delay as a function of increasing TMR for various constant low resistances (RL)

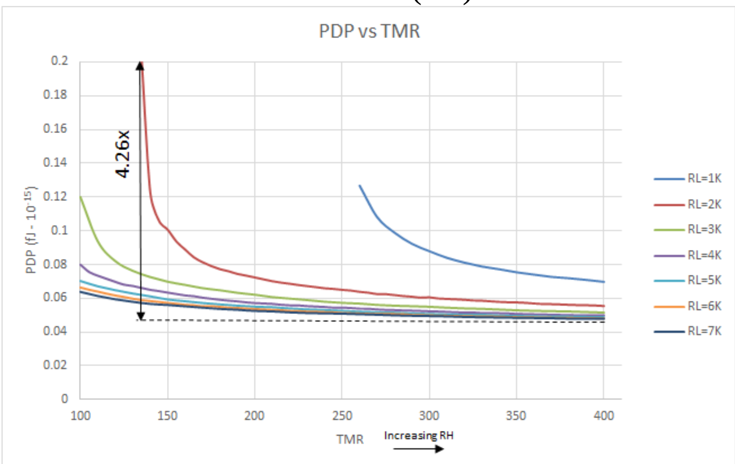

Figure 6. Observing Power Delay Product (PDP) as a function of increasing TMR for various constant low resistances (RL)

After choosing the most reasonably feasible TMR value of 400 % from the results mentioned above, the reference resistor (Rref) is optimized to further minimize power delay product as shown in Fig. 7. The value of 32.6 kΩ was found to be the most optimal reference resistor (Rref).

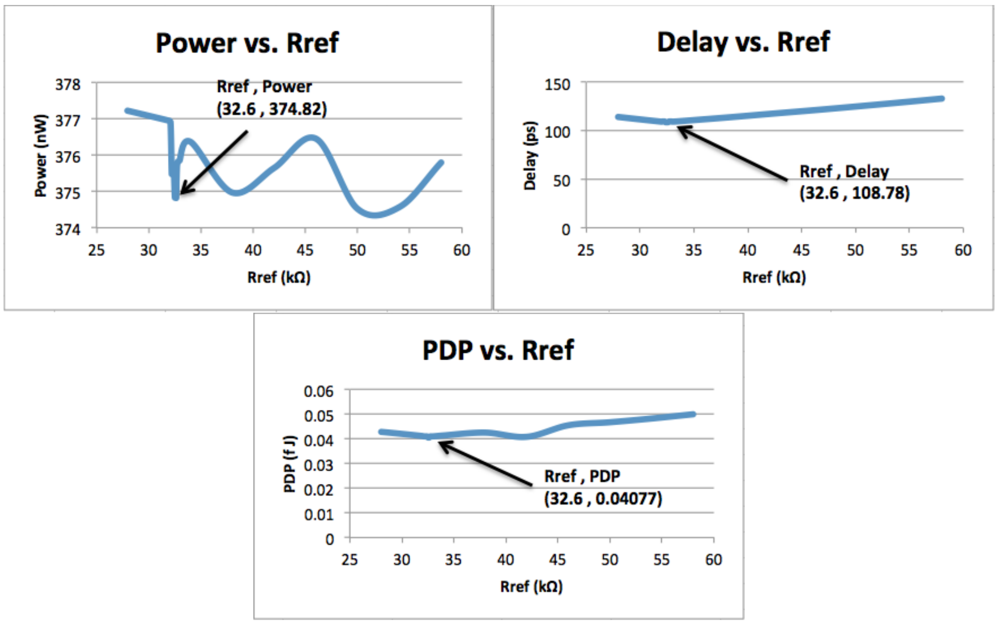

Figure 7. Graphs of a) Power, b) Delay, c) Power Delay Product of STT-LUT as a function of reference resistor value

With the improved reference resistor and the feasible value of TMR, the new power and delay results of STT-LUT were compared with the custom (i.e non-programmable) implementation of several logic functions in a standard CMOS technology. The logic functions considered include: 2-input NOR Gate (NOR 2); 2-input NAND Gate (NAND 2); and Inverter.

Firstly, the dependence of power as a function of output switching activity for standard designs was observed. Switching Activity (α) is expressed as follows:

$$\alpha = \frac{\text{No.of times gate output switches}}{\text{No.of clock cycles observed}} \qquad (4)^8$$

As shown in the Fig. 8, the power of LUT is independent of activity because its output switches every cycle. The power of the standard CMOS designs however increase by output activity increase. The results indicate that the STT-LUT dissipates more power than custom standard designs, which is due to its programmable and generic nature requiring additional hardware. However, the power overhead of STT-LUT is less at high activity factors.

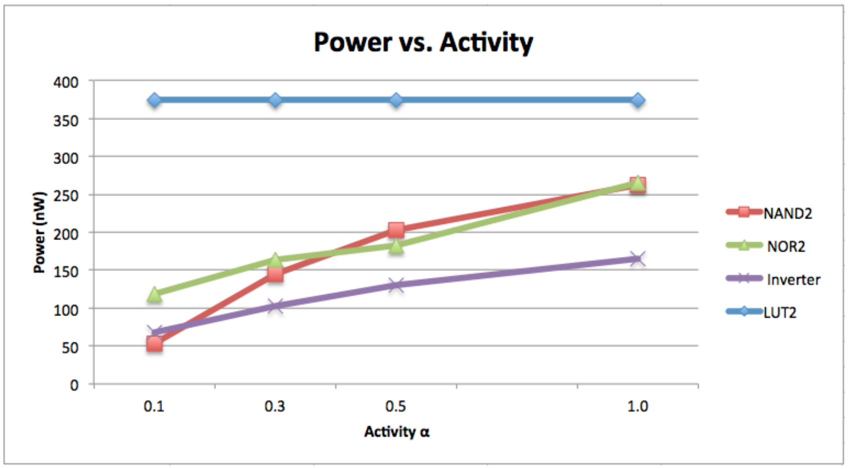

Figure 8. Graph comparing power as a function of activity for STT-LUT and standard design for logic function in CMOS

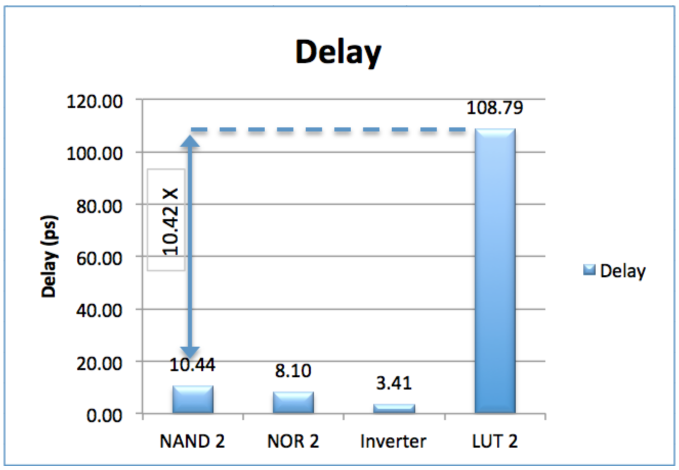

Figure 9. Chart comparing delay between STT-LUT and standard CMOS designs for logic functions

The delay comparisons between the STT-LUT and the standard custom (non-programmable) logic functions in CMOS are shown in Fig. 9. The graph illustrates that the delay of the STT-LUT is about 10 times higher than custom CMOS NAND-2 gate. This additional overhead is the penalty for the hardware reconfiguration offered by STT-LUT.

Student Surveys

Table 2 and 3 summarize the results of post-program student surveys designed to measure perception of overall impact of the research internship program on student participants in the past three years. Results show that the research internship program was successful in achieving its goals of helping students prepare for transfer, solidify their choice of major, increase their confidence in applying for other internships, and enhance their interest in pursuing graduate degrees. Overall, students were satisfied with the program, and would recommend it to a friend. The internship program was successful in achieving its goals of developing skills needed for students' academic success.

Table 2. As a result of your participation in the program, how much did you learn about each of the following? Response Scale: 1 – Nothing; 2 – A little; 3 – Some; 4 – Quite a bit; 5 – A lot.

Activity	2013	2014
Performing research	4.94	4.31
Designing/performing an experiment	4.88	4.50
Creating a work plan	4.81	4.69
Working as a part of a team	4.81	4.56
Writing a technical report	4.63	4.50
Creating a poster presentation	4.69	4.63
Making an oral presentation	4.81	4.50

Table 3. Tell us how much you agree with each of the following statements. Response Scale: 1 – Strongly Disagree; 2 – Disagree; 3 – Neutral; 4 – Agree; 5 – Strongly Agree.

Activity	2013	2014	2015
The internship program was useful.	4.94	4.56	4.69
I believe that I have the academic background and skills needed for the project.	4.63	4.44	4.38
The program has helped me prepare for transfer.	4.88	4.19	4.31
The program has helped me solidify my choice of major.	4.81	4.19	4.13
The program has helped me solidify my choice of transfer university.	3.75	3.56	4.06
As a result of the program, I am more likely to consider graduate school.	4.06	3.81	4.13
As a result of the program, I am more likely to apply for other internships.	4.94	4.75	4.75
As a result of the program, I am more likely to consider SFSU as my transfer institutions, or recommend it to others.	3.75	3.13	3.19
I am satisfied with the NASA CIPAIR Internship Program.	4.81	3.75	4.50
I would recommend this internship program to a friend.	4.88	4.56	4.63

Conclusion

Engagement of undergraduate students in nano-scale spin-electronics research was implemented via a summer research internship program. In the defined research project, the STT-LUT circuit was simulated to obtain optimal and feasible TMR values. Through investigation it was found that higher TMR ratios yield lower power and delay for STT-LUT. Furthermore, the reference resistor of the STT-LUT was optimized. Due to manufacturing constraints, high TMR values may be constrained. It was also found that the delay of STT-LUT is about 10 times higher than the delay of standard design of similar gates in complementary CMOS. That is the overhead for programmability of STT-LUT. The exit survey of the students participating in this research showed that the program achieved its objectives of developing skills needed for students' academic success.

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Curricular Impact of a Department of Energy Grant to Revitalize Electric Power Engineering Education

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University of the Pacific

Abstract
University of the Pacific was a member of an 82 university consortium (led by the University of Minnesota) that was supported by a three-year Department of Energy grant to "revitalize electric power engineering education by state-of-the-art laboratories." The grant, along with course and lab related resources provided by the lead institution, enabled University of the Pacific (whose Electrical and Computer Engineering department does not have a faculty member whose primary area of expertise is Power Engineering) to rapidly develop and offer a new course in power electronics with an associated state-of-the art lab. The grant also facilitated the addition of significant simulation content using an industry standard tool, PowerWorld, into the power systems course. One station of lab equipment pertaining to electric drives acquired via the grant has been used for independent study student projects and demonstrations in power electronics and control systems. The power electronics lab equipment has also been used for laboratory experiments in control systems. This paper describes the curricular changes effected by the DOE grant and provides links to the curricular materials developed by the lead institution. These resources are available in the public domain to any academic institution that wishes to use them. The paper also includes feedback from graduates on the importance of the grant-enabled curricular enhancements to their careers. Job placements of these graduates and the impact these courses have had on local and regional employers are also explored.

Introduction

The author joined the faculty of the Electrical and Computer Engineering Department at University of the Pacific in 2005, at which time the department had 7 faculty members. None of the faculty members had primary expertise in the area of electric power and energy systems (the one faculty member with such expertise had retired in 2002). The only course the department regularly offered in the area of energy systems was an elective course on energy conversion; a course that covered three phase systems, transformers, motors and generators, and some renewable energy topics.

The Electrical Engineering program at University of the Pacific has a mandatory cooperative (co-op) education program: all students who are U.S. citizens are required to work full-time with a co-op employer for a minimum of a regular semester and a summer. Mandatory co-op enables students to graduate with job experience, leading to better employment prospects upon graduation. The university has a co-op office that develops and maintains relationships with co-op employers and brings them onto campus every semester to conduct interviews that are the first step in hiring co-op students. Faculty members have the opportunity to interact with co-op employers over lunch during the interview period: this gives them a feel for skill sets that employers are seeking and provides a data point that can be used to ensure curricular relevance.

By the 2007 academic year these lunchtime interactions made it clear that a number of employers were seeking co-op students with skills in the area of power systems. These employers included consulting firms such as Carollo Engineers, CDM Smith, Kennedy Jenks, and ConSol, governmental organizations such as the California Department of Water Resources, and the Pearl Harbor Naval Shipyard, and utilities such as Nevada Power. In response to the demand from co-op employers, the author expended a great deal of time and effort over a summer to develop a power systems course, which was offered in Fall 2008. The course had eleven students, seven of whom are now known to be working in power and energy related fields.

It was later discovered that the demand for students with a background in power systems at University of the Pacific was local evidence of a nationwide need. In 2006, utilities and their associations formed the Center for Energy Workforce Development to "develop solutions to the coming workforce shortage in the utility industry" (http://cewd.org/about). In 2007, Prof. Chen-Ching Liu received a National Science Foundation (NSF) award to "organize a national forum to discuss critical issues and actions in response to the shortage of power engineering workforce in the future" (http://www.nsf.gov/awardsearch/showAward?AWD_ID=0704063). The executive summary of this workshop (Lauby et. al, 2008) says "Analyses suggest that there are not enough students in the pipeline who are excited about and prepared for a post-high school education in power engineering." In response to the findings of the workshop, the IEEE Power and Energy Society began an initiative called the Power and Energy Workforce Collaborative (http://www.ieee-pes.org/professional-development/workforce-collaborative), a partnership of industry, government, and universities working together to address electric power industry workforce challenges. The U.S. Navy also felt the need to address the workforce shortages in the power engineering area: the Office of Naval Research provided funding, beginning in 2006, to the University of Minnesota to conduct workshops to help reinvigorate power engineering programs at U.S Universities (Beidel, 2013). The author had the opportunity to attend a few of these workshops hosted by Prof. Ned Mohan of University of Minnesota (UMN) and his colleagues. The National Academy of Engineering also opined on the shortage of electric power engineers and the need for appropriate response at academic institutions (Russell, 2010).

In 2009, the Department of Energy announced a funding opportunity to "facilitate the development of a well-trained, highly-skilled workforce for the electric power sector to help implement the smart electricity grid" (https://www.fedconnect.net/FedConnect/?doc=DE-FOA-0000152&agency=DOE). Prof. Ned Mohan and colleagues at UMN submitted a proposal for funding after assembling a coalition of universities (including University of the Pacific) that would participate in the project. The proposal to create "A nationwide consortium of universities to revitalize electric power engineering education by state-of-the-art laboratories" was funded over the 2010-2013 period (http://www.doeconsortium.ece.umn.edu/). University of the Pacific was one of 82 consortium members that partnered with UMN under this award (hereafter referred to as the DOE grant) to revitalize power engineering education at their home institutions.

Curricular effects of the DOE grant at University of the Pacific

UMN as the lead institution provided access to curricular materials for its three undergraduate courses (Power Systems, Power Electronics, and Electric Drives) in the energy systems area. These curricular materials (course learning objectives, video clips, textbook information, and lab manuals) are available online to any university that wishes to use them (http://cusp.umn.edu/). These curricular materials and a timely sabbatical during Spring 2011 helped the author (whose primary area of expertise is in Signal Processing) to rapidly develop a new power electronics course and laboratory. The power electronics course and lab were offered during Fall 2011, after a hiatus of over seven years. Details regarding the development of this course and the subsequent curricular enhancements that were precipitated by the DOE grant are described below.

Development of a power electronics course and laboratory

Five stations of laboratory equipment were acquired for the power electronics lab. The heart of each lab station is the "Power-pole board" (PPB), a hardware platform that was developed at UMN with support from a NSF grant (Robbins et al., 2002). The PPB is a circuit board that can be quickly reconfigured to study a variety of power electronic converters including buck converters, boost converters, buck-boost converters, flyback converters, and forward converters. Ability to use a single board to study a large variety of converters makes the PPB very useful in a power electronics lab. Manufacture of the PPB has been commercialized; the board is available for purchase from Hirel Systems for a cost of $1250 (volume discounts are available). Table 1 lists components and costs associated with one power electronics lab station (http://cusp.umn.edu/assets/Vendor_Contact_Information_for_Hardware_Labs_and_Cost_Estimate.pdf). The tabulated cost below excludes an oscilloscope and desktop computer, which are assumed to be already available.

Item	Description	Distributor (Manufacturer)	Dist.# (Model#)	Quantity	Cost
Power-pole Board		(HiRel Systems; previously Schott)	75136	1	$1,250.00
Power Supply	0-40V 5A	NEWARK (BKPrecision)	06J2246 (BK1666)	1	$250.00
Signal Power Supply	Dual +/-12 V	DIGIKEY (SL POWER)	271-2482-ND (SW301MA0012F01)	1	$66.00
	Follow this link for recabling instructions for +/-12V power supply				
Differential Probe	100MHz	Newark (Tektronix)	83F2204 (P5200)	1	$731.00
Function Generator	0.2Hz - 2MHz	DIGIKEY (BKPrecision)	BK4010A-ND (BK4010A)	1	$250.00
Digital Multimeter		DIGIKEY (BKPrecision)	BK390A-ND (BK390A)	1	$167.00
Plug in board	20 pin proto board	DIGIKEY (Capital Advanced)	5020CA-ND (US-5020)	2	$6.62
Crimp Connectors	spade crimp	DIGIKEY	A0896-ND	10	$5.37
BNC Cable	3 feet	NEWARK (Pomona Electronics)	94B4227 (2249-Y-36)	2	$48.96
BNC Mini Graber		NEWARK (Pomona Electronics)	35F1061 (3788)	1	$11.76
Rheostat		NEWARK (Ohmite)	64K5833 (RKS25RE)	1	$55.46
Rheostat Knob		NEWARK (Multicomp)	10M7570 (MC21052)	1	$1.49
Banana Wire	Black	NEWARK (Pomona Electronics)	34F851 (B-36-0)	4	$26.72
Banana Wire	Red	NEWARK (Pomona Electronics)	34F850 (B-36-2)	4	$26.72
					$2,897.10

Table 1: Power Electronics lab station equipment and cost

One of the objectives of the DOE grant was for consortium partners to modify the UMN experiments to meet local needs, and possibly create new experiments. This has happened at University of the Pacific; the power electronics labs have undergone revisions, and new experiments have been developed to fit the local context. Current power electronics lab experiments include hardware experiments on buck converters, boost converters, buck-boost converters, and flyback converters. In addition, there are hardware labs on closed-loop voltage mode control of buck converters, peak current mode control of buck converters, and a lab evaluating the Texas Instruments LM 5118 buck-boost switching regulator. Software labs include PSPICE simulation of capacitors (to understand effects of equivalent series resistance, and equivalent series inductance), buck converters in discontinuous conduction mode, and synchronous converters. Apart from formal labs, significant PSPICE simulation is present in the course via in-class work and homework assignments. The course also includes a project on design, simulation, and implementation of a buck converter. The power electronics course and lab have been offered twice (Spring 13, Spring 15) after its first successful offering in Fall 2011. A total of 32 students have taken the course in its three offerings to date.

Addition of simulation content to the power systems course

The power systems course is a three unit elective that has no associated laboratory. The DOE grant enabled the author to become familiar with PowerWorld (www.powerworld.com) and PSCAD (https://hvdc.ca/pscad), which are software packages that are widely used for simulation of power systems. These simulation tools were used to enhance the power systems course, which now has PowerWorld well integrated via in-class examples, homework assignments, and projects. The Power Systems course enhanced with PowerWorld content has been offered three times (Fall 10, Fall12, and Fall 14) and a total of 39 students have taken the course. In addition to PowerWorld, PSCAD was introduced in the Fall 12 offering, and simulation using Mathworks' SimPowersystems (www.mathworks.com/products/simpower/) was introduced in the Fall 14 offering. Ability of students to use pertinent simulation tools is important in the context of securing employment. A student mentioned that he responded to an interviewer's question regarding use of simulation tools by stating that he had used PowerWorld and PSCAD. The student said that this response satisfied the interviewer and helped him secure the job (the company used different simulation tools, but exposure to alternate simulation tools turned out to be sufficient).

Use of the power-pole board in a control systems course

The Electrical and Computer Engineering department had not offered a control systems elective between 2005 and 2013 due to the retirement of the faculty member with expertise in the area. The interest of some students in control systems was piqued when they were exposed to closed-loop control of buck converters in the power electronics class. One of the students wanted to learn more about control systems and pursued independent study on the topic under the author's supervision. The author felt that the Electrical and Computer Engineering program and its students would benefit from availability of a control systems course. He subsequently prepared for and offered a control systems course in Spring 2014, and again in Fall 2015. These control systems courses did not have a dedicated three hour slot for lab work. Instead, about one hour per week interspersed between lectures was devoted to simulation-based labs using Matlab and Simulink. To give students some hardware lab experience, the PPB was used for a culminating lab experiment: closed-loop control of a buck converter using a Proportional + Integral (PI) controller. The PI controller design for this experiment used a traditional control systems approach that was very different from the K-factor approach used in UMN's power electronics lab curriculum. The PPB that was acquired for the power electronics lab served as a zero cost solution that provided meaningful hardware experience to students in a control systems lab. Thirty two students have taken the control systems course in the two offerings to date.

Independent study projects

One station of electric drives equipment was acquired in conjunction with the DOE grant. The equipment needed for an electric drives lab station and the associated costs are listed in Table 2. The motor sets include a permanent magnet DC motor, a permanent magnet DC generator (that can be used as an active load), a brushless DC motor, and an AC induction motor. The electric drives board has three switching power poles and can produce variable DC voltage of reversible polarity, and single phase or three phase ac voltages of varying amplitudes and frequencies. The DSPACE DSP board kit can be programmed to implement closed-loop feedback control systems via block diagrams in Simulink. It receives measurements of variables such as motor currents, voltages and speed as inputs and produces output pulse-width modulated signals that control the electric drives board.

Item	Description	Distributor (Manufacturer)	Dist.# (Model#)	Quantity	Cost
Motor Sets		Motorsolver Inc		1	$2,500.00
Electric-Drives Board		(HiRel Systems; previously Schott)	75550	1	$1,725.00
DSP Board Kit		dSPACE	ACE1104	1	$5,300.00
Signal Power Supply	Dual +/-12 V	DIGIKEY (SL POWER)	271-2482-ND (SW301MA0012F01)	1	$66.00
	Follow this link for recabling instructions for +/-12V power supply				
Digital Multimeter		DIGIKEY (BKPrecision)	BK390A-ND (BK390A)	1	$167.00
BNC Cable	3 feet	NEWARK (Pomona Electronics)	94B4227 (2249-Y-36)	2	$48.96
BNC Cable	2 feet	NEWARK (MCM Electronics)	35F1073 (2249-C-24)	2	$33.04
Power Supply	0-40V 5A	NEWARK (BKPrecision)	06J2246 (BK1666)	1	$250.00
Banana Wire	Black	NEWARK (Pomona Electronics)	34F851 (B-36-0)	4	$26.72
Banana Wire	Red	NEWARK (Pomona Electronics)	34F850 (B-36-2)	4	$26.72
					$10,143.44

Table 2: Electric Drives lab station equipment and cost

Two Master's students have used the electric drives equipment for independent study projects on motor control using digital signal processing and pulse-width modulation. One of these students now works for Sandia National Labs as an Electronics Engineer, and the other at Lawrence Livermore National Labs as a Controls Hardware Engineer. Another Master's student used the power-pole board and a Texas Instruments DSP board to experiment with digital control of buck converters. This successful project resulted in an international conference publication (Mathews & Mitsui, 2015) and a job placement in the control systems field for the student. This student, who now works at Western Digital, mentioned that his project excited great interest and provoked many questions at his job interview. In addition to use for student projects, the electric drives equipment has been used for demonstrations in the power electronics class (single phase and three phase inverters), the control systems class (motor control), and an introductory class taken by first year students in Electrical and Computer Engineering.

Impact of the curricular enhancements on program graduates and their employers

The development of the power electronics course and lab, enhancements to the power systems course, use of the PPB for hardware experiments in the control systems course, and use of the electric drives equipment and the PPB in independent study projects were all facilitated by the DOE grant. These elective courses (hereafter referred to as "grant-enabled courses") have had significant positive impact on the curriculum of the Electrical and Computer Engineering department and employment outcomes of its graduates. The courses have also benefited local and regional employers by providing a skilled workforce that they have been able to harness to meet their needs.

Table 3 lists the number of students who have taken the grant-enabled courses. The courses had a combined enrollment of 106 students during the 2010-2015 academic years. Twenty one students enrolled in more than one of the grant-enabled courses (one student took all four courses, two students took three of the courses, and the rest took two of the courses). A total of 43 of these students have graduated to date (most students from the Fall 2015 Control Systems course have not yet graduated). Thirty six of these graduates were Electrical Engineering (EE) majors.

Course	Number of students who have taken the course
Power Electronics	32
Power Systems	39
Control Systems	32
Independent study laboratory projects	3

Table 3: Student enrolment in the grant enabled courses

A survey was administered to the 43 graduates to obtain information about their employers, job functions, and impact of the grant-enabled courses on their careers. The survey began with a description of the courses developed and enhanced as a consequence of the DOE grant. It then solicited the following information:

1. Who is your current employer?
2. List your job title and provide a brief description of your job functions.
3. My work is in the field of power electronics, power systems or control systems. Answer Yes or No.
4. Material I learned in the power electronics, power systems or control systems courses is relevant in my current field of work. Answer Yes or No.
5. Please include any written comments on the relevance of any of these courses to your career.

Not surprisingly, only EE graduates responded to the survey (the grant-enabled courses are less relevant to non-EE majors). Seventeen out of the 36 EE graduates (47.2%) responded to the survey, which was sent to the university email address on file for each student. One of the 17 respondents is a recent graduate (December 2015), and is currently seeking employment. Another respondent earned a M.S. degree and currently works in Data Analytics as a software engineer. The remaining fifteen respondents all work in fields related to power electronics, power systems, or control systems, and answered "Yes" to questions 3 and 4 of the survey. The grant-enabled courses clearly contributed to the careers and career paths of the respondents. Information pertaining to the employment of these fifteen respondents is summarized in Table 4.

Six of the survey respondents are employed in governmental organizations; three of them work for or are associated with Department of Energy National Labs (Sandia, and Lawrence Livermore). This is indeed fitting given that funding for this curricular project was provided by the Department of Energy. The Office of Naval Research has funded similar curricular efforts (Beidel, 2013) and has reaped benefits; three of the graduates work at various U.S. Navy sites. All six of these graduates (group PE in Table 4) have taken the Power Electronics course and at least one more of the grant-enabled courses. Not surprisingly four out of six of them have the job title "Electronics Engineer."

Name of Employer	Job Title	Type of employer	Group
U.S. Navy, Point Mugu, CA	Electronics Engineer	U.S. Navy	**PE**
U.S. Navy, Port Hueneme, CA	Electronics Engineer	U.S. Navy	
U.S. Navy, Keyport, WA	Electronics Engineer	U.S. Navy	
Lawrence Livermore National Lab Livermore, CA	Controls Hardware Engineer	National lab	
Sandia National Lab Livermore, CA	Electronics Engineer	National lab	
National Security Technologies (Livermore, CA site)	Engineer 1	National lab	
Damatt Engineering Stockton/Oakland, CA	Associate Engineer-Industrial Control Systems	Consulting: Industrial automation and power systems	**PS**
CH2M Hill, Portland, OR	Instrumentation and Controls Engineer	Consulting: Industrial automation and power systems	
Damatt Engineering, Stockton/ Oakland, CA	Associate Engineer - Power Systems	Consulting: Industrial automation and power systems	
Nor-Cal Controls Energy Solutions Diamond Springs, CA	Automation Engineer	Consulting: Industrial automation and power systems	
Glumac, San Francisco, CA	Electrical Engineer	Consulting: Building and facility design	
S&S Taylan Electric, Waipahu, Hawaii	Project Electrical Engineer	Electrical design related to construction	
Modesto Irrigation District, Modesto, CA	Electrical Engineer – Substation	Utility (non profit)	
Sunverge Energy, Stockton, CA	Electrical Engineer	Local company (utility related)	**C**
Western Digital, Fremont, CA	Senior Engineer -Control Systems	Large corporation	

Table 4: Job placements of Electrical Engineering graduates who took grant enabled courses

The next 7 survey respondents (Group PS in Table 4) have all taken the Power Systems course. They work in areas of industrial automation and power systems, design associated with construction of buildings and facilities, or in utilities. The majority of the employers in this group are consulting firms that provide services such as power system design, analysis and support; design of Supervisory Control and Data Acquisition (SCADA) systems for power plants; design of industrial control systems; PLC (programmable logic controller) programming; HMI (human machine interface) system development; design of electrical distribution, lighting, and fire alarm systems for buildings and facilities. There is also a utility employer; engineering work at this site involves design and operation of electrical substations.

The final group C consists of two corporate employers. The first is Western Digital; a large corporation, where work involves control system design for hard drives, along with associated coding, testing, debugging, and failure analysis. The other employer (Surverge) works with utilities to provide distributed storage for the consumer market. Work at this site involves research and development, design, testing, and debugging for residential solar power systems. Both graduates in this group have taken the power electronics course and least one more of the grant-enabled courses.

The author is especially pleased about the local impact of the curricular enhancements enabled by the DOE grant. Two employers (Damatt and Sunverge) with offices in Stockton, the home of University of the Pacific, have hired three of the survey respondents. Another seven of the survey respondents work within a 100 mile radius of University of the Pacific. The knowledge and skills that graduates have gained from the grant-enabled courses have made an impact on the local and regional economy.

Excerpts from some of the written comments of the graduates on the relevance of the curricular enhancements to their careers are included below. These comments show that knowledge gained from the grant-enabled courses is very relevant to the careers of the graduates.

- All of these courses are relevant to my career. The systems I work on have three phase AC power and induction motors. I work with motor motion controls (single phase and three phase motors) and control system characterization and development.
- As described in my job description, I am working in the field of control system engineering. I am consistently making loop and notch designs to improve hard drive quality. The Power Electronics and Control Systems courses I have taken at the University of the Pacific, taught me the essential topics needed for my career. These courses also gave me more experience using Matlab, Simulink and Oscilloscope tools, which I use daily in my career.
- The power electronics course did a fantastic job of showing practical application of electronics, as well as teaching the basics of an important part of electronics - power supplies and regulation. In the process of showing practical applications it also demonstrated the realities of parasitics and their effect on actual built systems; invaluable knowledge to students who plan to go into design. Independent study also acted as an excellent continuation course of a required course (Signals and Systems), which again

tied real world systems to the theory learned in that previous course. Specifically learning about motor control was not only a great way to see tangible applications of control systems, but also introduced me to some of the mechanical realities of control systems as well. These two courses really enriched my education at Pacific.

- I use material learned from both Power Electronics and Power Systems on a daily basis. I definitely had a head start over other new engineers that were not able to study these topics while in college.
- Given the nature of SCADA systems for power plants, my job position requires a strong understanding of how power transmission systems work and how to control them properly. My educational experience that I gained from taking the Power Systems and Control Systems courses has been crucial in being able to grasp these concepts. I regularly work with many different devices and systems at power plants both at high level and low level, and the experience I attained in these courses is vital to understanding both of these points of view.
- Power systems is currently the most relevant to my career. Basic 3 phase power theory is the core of my job. The progress made at UOP has been great for engineers interested in power systems.
- All of the three courses I took have been and are useful in my career. I use the AC theory (delta, wye, phase shifts, etc.), power electronics theory (power supplies, ac/dc converters, etc.), and control systems theory (feedback loops, etc.) almost every day. These courses are very well laid out and easy to follow.

Conclusions

A Department of Energy curricular grant has enabled significant improvements to the electrical and computer engineering curriculum at University of the Pacific. A survey of graduates shows that the new courses developed, and the curricular enhancements enabled by the grant, are foundational to their careers. A majority of the survey respondents work within a 100 mile radius of the university: the DOE grant has thus benefited local and regional employers by helping provide graduates who are trained in fields of power electronics, power systems, and control systems. The Department of Energy and U.S Navy have themselves benefited from their investments in curricular enhancements at universities; a number of the graduates who availed of the curricular enhancements now work for DOE National Labs and the U.S. Navy. Any university that wishes to modernize or develop new courses in areas of power systems, power electronics, or electric drives, can access curricular resources associated with the DOE grant. These resources are available from the principal investigators at University of Minnesota (http://cusp.umn.edu/).

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A Single-Course Approach to Computer Design and Assembly Language Programming

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Abstract
Engineering curriculums generally present a wide breadth of topics but with enough depth to leave students with viable skills upon graduation. Widening the breadth of topics can effectively lower the depth of the topics in a course based on constant time-to-graduation rates. This paper describes an approach to presenting the topics of computer design and assembly language programming in a single course. The main goal of this approach is to maintain the breadth of subject matter without sacrificing the depth of the material. Our approach uses the home-grown RAT microcontroller (MCU) and associated courseware. The RAT MCU is simple enough such that students can build it in a single course and also use it to learn assembly language programming. Students model the RAT MCU architecture using VHDL and then test their assembly language programs on the synthesized hardware. We meet the course learning objectives using several approaches that mitigate the time constraints associated with the presenting the breadth of course topics. Our course design includes a textbook, an assembler manual, a laboratory manual, and an assembler/debugger. We present the course material in a 10-week span with six contact hours per week. Additionally, we present the course using a studio format in order to emphasize the laboratory aspect of the course.

Introduction
This paper describes a single course that covers major aspects of computer design and assembly language programming. This course is the second course in the digital series; the first digital course provides a background of basic digital principles including basic logic gates, combinatorial and sequential digital circuits, and finite state machine (FSM) design. Our course requires students to implement a complete computer, which is possible because FPGA-based development boards have freed them from the drudgery of hand-wiring circuits. This course has been in a constant improvement cycle since it was first taught in 2011. Implementing this course required us to address two major problems. First, the topics and skills associated with computer design and assembly language programming are quite extensive. Second, there is no off-the-shelf courseware that adequately supports the course topics in the given time frame. The main motivation behind our work is to solve these two problems, while not increasing the financial hardship that many students face.

Economics remains a major obstacle to higher-level education (Koch, 2006) so we opt to provide the courseware at no cost. The notion of free learning materials is not new (Buckner, 2006), but it has gained momentum with recent government legislation (Steinberg & Alquist, 2012). While there is a significant amount of free materials available, we found that many of them had issues such as small instruction sets (Smallwood & Lofty & Sanders, 2014),(Stanley et al., 2013) or targeted an audience with limited digital hardware backgrounds (Sondag & Pokorny & Rajan, 2012). Additionally, while there are many excellent textbooks that cover the required course topics, they do so with levels of detail that are not conducive to the relative short duration of our course (Harris & Harris, 2007).

The various sections of this paper provide an overview of the course, which includes descriptions of the RAT MCU architecture, the RAT MCU instruction set, the RAT MCU assembler, as well as other notable courseware features. We designed the RAT MCU and courseware specifically to support students new to computer design and assembly language programming. The textbook provides an overview of digital hardware, descriptions of the RAT MCU architecture and instruction set, and an introduction to assembly language programming. The assembler manual describes the instruction set and the RAT MCU assembler functionality. The laboratory manual guides students through the piece-wise development of the RAT MCU, which students model and synthesize on an FPGA-based development board.

Course Evolution

This course was first taught in 2003 and was primarily centered around the PicoBlaze (Chapman, 2003) MCU. The PicoBlaze MCU is ideal for students new to assembly language programming because its instruction set is relatively simple but contains enough instructions to provide students with a viable assembly language programming experience. Although the PicoBlaze MCU was ideal for the assembly language portion of the course, we found it problematic for the computer design aspect of the course. First, the PicoBlaze models were highly optimized and not readily understandable to people new to the hardware design language or computer architecture. Secondly, the available documentation provided excellent reference material for the microcontroller but was less useful as learning materials for students new to the topics. The final issue was that the PicoBlaze models were vendor-specific, which places limits on development board selection.

We feel that the best approach to these topics is to have students design a complete computer, and then use that computer to execute assembly language programs. Our hope is that requiring students to implement the instructions in hardware will provide them with insights about using those instructions in assembly language programs. We created our own MCU because we felt that creating courseware is less problematic than adapting existing courseware to meet the course learning objectives. This home-grown courseware subsequently provides a starting point from which we can develop our own special "learning" features for both hardware and programming aspects of the course. While the PicoBlaze was our main inspiration for the RAT MCU, we also borrowed various ideas from Atmel AVR MCUs and assembler.

Motivation

The underlying theme of this course is that designing a computer is the next step in digital design after learning about standard digital hardware. While the notion of computer design may seem daunting to students entering the course, we aim to have students be comfortable with the topic after completing the course. Specifically, the course emphasizes the following ideas:

1) A computer is a set of standard digital modules controlled by a FSM
2) Computer design represents a set of arbitrary engineering decisions, with the first decision being the instructions the hardware will support

We support this emphasis by having students use VHDL to model the RAT MCU architecture. In particular, students implement instructions on the RAT MCU architecture by modeling each instruction in the RAT MCU's control unit. Additionally, we take several approaches to reduce the workload of the course, which facilitates modeling the RAT MCU and later programming the synthesized computer:

1) We provide the completed RAT MCU architecture diagram to students. Students must understand this architecture in order to implement the RAT MCU instruction set.
2) The RAT MCU is primarily comprised of standard digital modules. Students use VHDL templates as starting points to module design, which they modify to meet the various architectural specifications.
3) Students gain familiarity with the instruction set because they have implemented each instruction in hardware.

RAT MCU Architectural Overview

The RAT MCU is simple enough such that students can quickly model it but complex enough to provide a meaningful learning experience in both computer architecture and assembly language programming. Figure 1 shows the RAT MCU programmer's model while the following lists the major RAT MCU architectural features.

- 8-bit RISC-based Harvard architecture with 48 instructions
- Two condition flags (C & Z)
- Programmed I/O with one interrupt
- 32 general purpose 8-bit registers
- Two clock cycles per instruction execution
- 1024 location instruction memory (18-bit instruction words)
- 256 location scratch memory (stack and generic data storage)

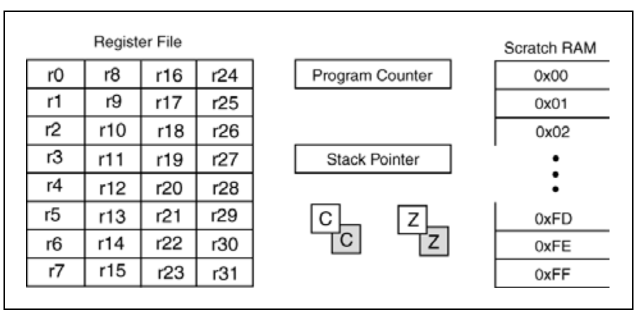

Figure 12: RAT MCU programmer's model.

RAT MCU Instruction Set Architecture

The RAT MCU instruction set contains 48 instructions, which we feel represents a minimum number of instructions to support a comprehensive assembly language programming experience. Table 1 shows the five instruction types supported by the RAT MCU with example assembly language instruction mnemonics.

Instruction Type	Example
Register/Register	ADD r0,r1
Register/Immediate	ADD r2,0x56
Register	PUSH r5
Immediate	CALL My_sub
None	RET

Table 5: RAT MCU instruction types and examples.

While implementing the RAT MCU's 48 instructions in hardware may sound daunting, the instruction formats mitigate the time required to implement these instructions. For example, there are two instruction formats for most of the ALU-based instructions, which means that 20% of the instructions differ from another 20% of the instructions by a value of a single control signal. Table 2 shows a complete list of RAT MCU instructions. Other key instruction features include:

- Two address modes: immediate and register indirect
- Four conditional and one unconditional branch instructions
- Four interrupt support instructions
- Two types of memory access instructions (stack and address-based)

Logical		**Arithmetic**		**Storage**	
AND rX,kk	AND rX,rY	ADD rX,kk	ADD rX,rY	ST rX,imm	PUSH rX
OR rX,kk	OR rX,rY	ADDC rX,kk	ADDC rX,rY	ST rX,(rY)	POP rX
EXOR rX,kk	EXOR rX,rY	SUB rX,kk	SUB rX,rY	LD rX,imm	
TEST rX,kk	TEST rX,rY	SUBC rX,kk	SUBC rX,rY	LD rX,(rY)	MOV rX,rY
		CMP rX,kk	CMP rX,rY		MOV rX,imm
Program Control		Misc	Shift & Rotate	Input/Output	Interrupt
BREQ label	BRN label	CLC	LSL rX	IN rX,pp	RETID
BRNE label		SEC	LSR rX	OUT rX,pp	RETIE
BRCS label	CALL label	RSP rX	ROL rX		SEI
BRCC label	RET	WSP rX	ROR rX		CLI
			ASR rX		

Table 6: RAT MCU Instruction Set

RAT MCU Assembler

The RAT MCU assembler provides functionality similar to that found in assemblers for more complex MCUs. The assembler utilizes eight directives and other features that aid beginning assembly language programmers. Table 3 lists the RAT MCU assembler directives along with a brief description.

Directive	Description
.CSEG	Indicates code segment
.DSEG	Indicates data segment
.ORG	Specifies segment information placement
.EQU	Associates numeric values with strings
.DEF	Associates registers with strings
.BYTE	Reserves uninitialized memory
.DB	Reserves and initialize memory
.INEW	Associates unimplemented instructions with strings

Table 7: The RAT MCU assembler directives.

Unique Courseware Features

We designed RAT MCU and associated courseware to support learning both computer architecture and low-level programming. As a result, our design has several features and attributes that support the overall presentation of the course material to students new to the course topics. This section describes some of the more notable features of our design.

Courseware Price Point: Because the RAT MCU is a homegrown design, we control all aspects of the courseware. This has two distinct advantages. First, the course can be potentially taught at no cost to students. Because all aspects of the courseware are free, the only potential cost to students is the price of the development board. Second, courseware enhancements and bug fixes happen immediately and as often as necessary.

Laboratory Manual: The RAT MCU lab manual primarily leads students through an incremental assembly of the RAT MCU. Initial experiments build subsections of the computer, while later experiments involve integrating the subsections to complete the full RAT MCU. Most experiments build on each other so students can reuse their initial circuits in later experiments. Additionally, students must cross-reference the RAT MCU assembler manual in order to complete their RAT MCU designs, as the manual describes the instructions and associated bit formats.

RAT MCU Schematic Provided: Because the course's duration is relatively short, we provide students with the final RAT MCU schematic at the beginning of the course. While this may seem generous, the course still requires students to understand all aspects of the RAT MCU hardware. The courseware takes the approach of explaining basic low-level computer concepts in the context of incrementally building a working computer. Understanding the low-level hardware facilitates modeling the RAT MCU including low-level instruction implementation.

Textbook Format: The RAT MCU textbook separately supports both hardware design and assembly language programming. This enables students only interested in assembly language programming to use the textbook and simulator. A more complete description of the RAT MCU textbook appears in a previous paper (Mealy, 2015).

Interrupt Architecture: The RAT MCU includes one external interrupt. Although the associated interrupt architecture is relatively simple, implementing it in hardware provides students with a solid introduction to real-time programming issues. Students address more complex real-time issues later in the curriculum.

Look-Up Tables (LUTs): The RAT MCU courseware uses the assembler in conjunction with register indirect memory access instructions to support LUTs. This requires students to understand both the use of LUTs as well as how the assembler generates them. Programmers use the .DB directive to instruct the assembler to generate and insert “start-up code” into the program before the programmer’s code. Students must understand the start-up code mechanism in order to correctly position their programs in instruction memory. The RAT MCU includes the concept of code and data segments, where the data segment supports memory initialization.

Assembler Error Message Generation: The RAT MCU assembler includes a significant amount of reporting regarding any errors it encounters in the assembly code. This feature aids novice assembly language programmers by helping them find and quickly correct their errors.

Stack Implementation: The RAT MCU uses a single memory for both the stack and generic data storage. This requires students to be aware of various stack integrity issues and their relation to data memory size and defined data placement. Additionally, the RAT MCU instruction set includes instructions to either read or write to the stack pointer, which students can use to manipulate programs in potentially non-standard ways.

Peripheral Interfacing: When students successfully synthesize the RAT MCU, they can use it to interface with various computer peripherals. This includes both off-the-shelf peripherals and peripherals modeled using an HDL and synthesized along with the RAT MCU hardware. This often proves to be the most popular part of the course as students are typically more engaged when they are given the opportunity to work on projects of their choosing.

Unimplemented Instructions: The RAT MCU assembler supports a set of unimplemented instructions for each of the five instruction types. These instructions have generic names, which students access using the .INEW assembler directive. This directive allows programmers to substitute instruction mnemonics they create for the various unimplemented instructions. The unimplemented instruction mechanism gives students the flexibility of implementing instructions of their choosing in the RAT MCU hardware and have those instructions fully supported by the assembler. Table 4 shows an example of the unimplemented instruction feature.

Example Code	Description
.INEW UI_RR_00 X_my_instr	The assembler directive associates the string "x_my_instr" with the unimplemented instruction UI_RR_00, where the "RR" refers to a reg/reg-type unimplemented instruction.
X_my_instr r1,r2	Generates the machine code associated with the UI_RR_00 instruction.

Table 8: Unimplemented instructions and the .INEW assembler directive.

Course Implementation Issues

Assessing the efficacy of the course presents several challenges, with the primary one being that the course has been in constant development since its first offering in 2011. We have generally focused our efforts on basic improvements to the course and opted to rely on department sponsored evaluations in order to address non-obvious issues students have with the course. This course presents two main issues for students: preparedness and workload. The scope of the course material effectively requires that instructors start the course with new topics as inherent time constraints discourage extensive review of prerequisite material. We primarily deal with this issue by having initial experiments that review pre-requisite material, but in the context of digital circuits that are similar to computer-type circuitry. Additionally, we have modified various aspects of the courseware in order to reduce the course workload, which has resulted in changes such as simplifying the RAT MCU hardware, focusing experiments on the development of the final RAT MCU, and creating a textbook for the course.

The course itself is challenging, but two external issues inadvertently present more challenges to students. First, the course is not a course in VHDL, but it does require student to have a working knowledge of VHDL in order to model the RAT MCU. Students learn VHDL concepts in the first digital design course, but many students do not take our course in the following quarter. The second issue is that students take the course in a laboratory that contains more benches than can adequately be "managed" by the instructor. Instructors are expected to use teaching assistants to help students that they themselves do not have time to help.

Conclusions

The RAT MCU and associated courseware provides students the opportunity to build a complete 8-bit computer and write assembly language programs to run on their computer in a single course. We use several approaches to ensuring a wide breadth of course topics but with sufficient depth to ensure students meet the course learning objectives. We designed the RAT MCU and courseware to specifically support students new to the subject matter and further support students by offering the courseware at no cost.

The major student issues with the course involve the overall workload. These issues are exacerbated by student not retaining knowledge from the pre-requisite course and overcrowding in the laboratory where the course is taught. We are focusing our ongoing development efforts on addressing these issues, primarily by simplifying the RAT MCU hardware and making modifications to the supporting experiments. Our current changes are relatively minor compared to when the course was first offered. Based on the recent students comments, these are still areas that need further development. Additionally, student comments generally give the textbook and other supporting materials for the course a favorable rating. We feel it is worth noting here that our approach to the course has been adopted by all instructors who currently teach the course.

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Training Future Scientists in Sustainable Sanitation through International Research Experiences (IRES)

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Abstract
Ensuring that new engineers are prepared to be productive citizens and professionals has led to efforts of incorporating globalization in U.S. engineering education (Chan & Fishbein, 2009; Grandin et al., 2009). Greater scientific self-efficacy (directly related to students' confidence in their ability to carry out scientific research), research experiences in supportive and non-threatening nurturing environments, and a sense of belonging to the community of science, have been identified as factors that provide enriching student learning experiences and positive attitudes toward science (Cheryan et al., 2013; London et al., 2012; Lopatto, 2007; Myers & Pavel, 2011; Russell et al., 2007; Seymour et al., 2004). Research experiences also increase student interest in pursuing higher education and careers in Science, Technology, Engineering, and Mathematics (STEM) related fields (Russel et al., 2007). This paper describes the development of research and globalization skills among students participating in the Sustainable Sanitation Project in Durban South Africa (SA) as part of NSF's International Research Experiences for Students (IRES) Program. The SA IRES program objectives are to develop (1) undergraduate and graduate engineering students' technical expertise, (2) professional identities as engineering researchers, and (3) a sense of community with other SA IRES scholars. To prepare the students for a successful research experience in SA, a series of pre-departure activities were designed, including team building dynamics, cultural sensitivity exercises, SA historical and contemporary facts, packing tips, literature review training, research ethics, graduate school experience, safety practices in the laboratory and the field, hands-on experiment development, and undergraduate-graduate mentoring opportunities. To evaluate the effectiveness of the IRES program, participants completed a questionnaire before the program, an interview after the summer research experience, and a final questionnaire after the program. The questionnaire assessed students' attitudes about the program, research skills, identity as an engineer, graduate school and career plans in engineering, and sense of community. An analysis of the post-program interviews and questionnaires indicates that the program was successful and participants found all aspects of the program valuable or very valuable. Students reported learning much more about environmental engineering, advancing their research skills, and strengthening their intentions to pursue a career in environmental engineering. In a comparison of the pre- and post-program questionnaires, participants reported greater research skills after completing the program including the ability to ask pertinent questions about complex issues, formulating testable research questions, and identifying limitations of research methods and designs. Further, participants had stronger intentions to pursue a PhD in engineering after completing the program. Due to the small sample size, the results reflect marginal trends. The IRES program first-year evaluation supports the notion that international research experiences

induce greater self-efficacy and positive attitudes toward science in students, while broadening their participation in environmental engineering. Moreover, harnessing the transformative cultural experience resulted in a positive impact on each student and has enhanced the global engineering curriculum component, which merits further investigation.

Background

US challenges in engineering education. The evolution of engineering education to properly train and equip current engineering students and "future professional engineers" is regarded as paramount. Recently, the National Academy of Engineering has also recognized 14 Grand Challenges for engineering in the 21st century, including restoring and improving urban infrastructure and providing access to clean water. To prepare students for the critical global challenges, educators across the world are working together to maximize their institutional resources and enhance student global education and skills. In just such a collaboration, San Diego State University (SDSU) and Cal Poly Pomona (CPP) developed an international research experiences for students (IRES) program with the University of KwaZulu-Natal (UKZN), Durban, South Africa (SA). The project objectives were to train US engineering students in novel environmental engineering topics, such as net-zero waste, and energy and resource recovery from wastewater in under-served communities, while exposing participants to the South African culture and societal environments. It was anticipated that these experiences would provide students with a global perspective of challenges faced in South Africa by under-served communities in formal and informal settlements surrounding the City of Durban.

Integrating teaching and research in undergraduate education. Active learning and research experiences have been defined as very effective pedagogical techniques to engage and motivate undergraduate students in their major (Braxton et al., 2000; Meyers & Jones, 1993). Moreover, the use of research projects as a way to instill a higher level of thinking in undergraduate students has been widely proposed as a high impact teaching practice (Hunter et al., 2006; Laursen et al., 2010). The Council on Undergraduate Research (CUR) promotes high-quality undergraduate education through student-faculty collaborative research. CUR promotes the transformation of the curriculum in undergraduate teaching institutions from the typical lecture-based setup to an inquiry-based or research-based education. In the latter format, students acquire knowledge under a controlled environment while being directed by the faculty advisors and solving complex problems. The use of research as part of educational training exposes undergraduates to hypothesis formulation and testing, data collection and analysis, awareness of the relevance of the findings, and scientific communication of discoveries (e.g., through short journal papers, posters or oral presentations). Thus, curricular changes to include research experiences and global learning at the undergraduate level have been identified as critical to enhancing the student learning experience and development of skilled problem solvers prepared for the challenges of the 21st century. This paper describes the implementation of an international research experience between SDSU, CPP and UKZN where participants become members of a team of researchers, contributing to environmental engineering problems in peri-urban communities of Durban, South Africa.

International research experience. The purpose of the project is to give five US graduate and undergraduate students, recruited from SDSU and CPP (both campuses with a high percentage of under-represented students), the opportunity to conduct research activities at UKZN, in Durban, South Africa every boreal summer for three years. The research projects vary depending on the activities of the Pollution Research Group (PRG) at UKZN, but all topics are related to resource and energy recovery from wastewater, new perspectives on wastewater treatment, and sustainable sanitation in under-served and heavily populated communities. This project was intended as a research experience that would allow upper-level undergraduate and MS graduate students to envision themselves as researchers, equipped with the research skills they need to advance into graduate school or doctoral program. Students would learn about the sanitation conditions faced in a different country and be exposed to problem-solving opportunities with the tools available at UKZN. In addition to the expected strengthening of participants' research skills, it was expected that graduate students would have the opportunity to develop mentoring skills. While working on novel research at the nexus of water, energy, and food with the PRG at UKZN, participants also would obtain an enriching international experience by being immersed in the South African culture and living in Durban. This project approach provided a first-hand global research experience that allowed the students to recognize how their work and research results will influence a peri-urban community in Durban. It was expected that this international research experience would enable them to become conscientious and contributing professionals in the world (Chan & Fishbein, 2009; Grandin et al., 2009). It was hypothesized that awareness of the contribution to the environment and the international community would produce a positive effect on participants' attitude toward pursuing a higher degree.

IRES program description. Students involved in the Sustainable Sanitation IRES program were immersed in an experience that exposed them to an international view of engineering solutions coupled with societal needs where resources are limited. Thus, participants received technical training related to wastewater treatment and sustainable solutions, field research techniques, and cultural sensitivity. Table 1 summarizes the activities that were developed to help the students achieve technical competency, develop their professional skills, and form a community with each other and the faculty mentors.

Table 1. IRES activities and their relevance to program objectives

Development of Technical Expertise	Professional Development	Community Development
• Pre-departure online assignments (technology summary, literature review) • Pre-departure open ended, hands-on environmental challenge • Research basics and ethics workshops • Intro to individual research project in Durban • Lab and field safety training • Cultural sensitivity and history of South Africa	• Pre-departure seminars on graduate student experiences • Posting on program's Facebook page • Graduate student panel • DropBox database • Poster presentation workshop • Conference presentation	• Development of cultural and research experience video (post return) • Outreach to US K-12 students after the IRES experience • Tour of Durban, lunches and dinners as group • Cohort trust development via group dynamics

At UKZN, the IRES students worked directly with the director of the PRG and a project manager. The project manager oversaw the day-to-day operations of an anaerobic wastewater treatment system at the field station and guided the students in their interactions with on-site staff and laboratory personnel.

Evaluation goals and study variables. The purpose of the evaluation is to assess whether the research team made satisfactory progress toward achieving the project objectives. In addition, data collected as part of the first year evaluation helped inform the investigators of potential project and/or research improvements. The end of cohort 1's program culminated in K-12 outreach and research presentations at regional and international conferences. The evaluation plan testing methods considered development of the following project goals for undergraduate and graduate engineering students: (1) technical expertise, (2) self-identification as professional engineering researchers, and (3) a sense of community with other IRES scholars.

Participants' program learning objectives. The learning objectives of the program addressed several aspects of project goals 1 and 2 described previously. The program provided students with the ability to:
1. Apply basic environmental science knowledge and engineering skills toward developing technological innovations.
2. Learn research skills and strengthen them during the period of the IRES program.
3. Demonstrate the capacity for self-directed learning and original investigation.
4. Identify and incorporate the elements of sustainable development into students' research projects.
5. Strengthen skills for communicating scientific and engineering concepts to the public and to K-12 students.

Evaluation questions. Formative evaluation questions included the following:
- Is the project team making satisfactory progress toward achieving their project objectives?
- Did the team recruit a diverse pool of applicants? If not, what changes should be made?
- Did implementation of the project occur as planned, and are modifications necessary?
- What is the initial impact of the program on achieving student learning objectives? For example, are students learning necessary skills in the orientation (e.g., science lab safety)?
- Does the project team expect to make valid conclusions based on the data they have received?

Summative evaluation questions include the following:
- To what extent did the project team achieve their objectives?
- To what extent are the project outcomes, as reported by the research team, valid?
- What is the overall integrity of the project team's assessment of project outcomes?

Methods

Participants. The five selected students included one graduate student and four undergraduate students. The sample was 60% female and 60% racial minorities (one African male, one Asian male, one Latina woman, and two Caucasian women). Two students were from SDSU and three from CPP.

Evaluation design. Evaluation instruments and protocols were prepared with input from SDSU and CPP investigators. The evaluator conducted reviews of project materials (e.g., handouts, training schedules), reviewed research materials (e.g., presentations, project reports), and conducted observations of the online community components (e.g., videos). In addition, the evaluator conducted post-trip interviews with the principal investigator, collaborators, faculty members, and program participants. In total, five student participants, SDSU and CPP investigators, and all PRG collaborators and staff were interviewed. Table 2 summarizes the methods used to assess the effectiveness of reaching each objective.

Table 2. Project goals, products, measurable outcomes, and methods

Project Goals	Product	Measurable Outcomes	Method
Development of technical expertise	Pre-departure online assignments (technology summary, literature review)	Completion of assignments, quality of tasks performed	Descriptive statistics of grades, qualitative analysis of assignment quality
	Research basics workshop	Basic research skills	Pre/post-test of factual knowledge
	Research project in Durban	Assessment of learning objectives based on faculty observations, student self-reports, and quality of completed projects	Interview with faculty and students, quantitative assessment of research products
	Research presentations	Conference presentation, awards received	Faculty observation data
	Contribution to research or educational paper	Publishable paper, journal impact factor	Faculty and student interviews, journal impact factor, article citation record
	Research productivity after the program	Conference presentation, awards received; Publishable paper, journal impact factor	Follow-up questionnaires with participants in Years 2 and 3; examination of products
Professional development	Pre-departure seminars on student experiences	Attendance and participation in seminars	Post evaluation questionnaires of seminars; intentions to pursue graduate school and research careers in engineering; assessed after seminars and post-program
	Posting on program's Facebook page as an online journal of the research experience	Number of likes, shares, and friends	Student interviews on Facebook effectiveness, quantitative quality ratings in post-program questionnaire
	Use of twitter for program updates and announcements	Frequency of posts, shares	Student interviews on Twitter effectiveness, quantitative quality ratings in post-program questionnaire; qualitative

			assessment of journals; faculty observations
Professional development	Develop identity as engineering researcher		Pre/post-program questionnaire
	Graduate student mentoring	Student will acquire confidence to support peers; student mentors will support training of other students	Number of students mentored; mentors interested in engineering research career; Student and faculty interviews; faculty observation; post-program questionnaire
	Post-trip seminar on student experiences	Attendance and participation in seminar	Post evaluation questionnaires of seminar; intentions to pursue graduate school and research careers in engineering; assessed after seminars and post-program
Community development	Posting on program's Facebook page	Number of likes, shares, and friends	Student interviews on Facebook effectiveness, quantitative quality ratings in post-program questionnaire; faculty observations
	Cultural experience via a field trip	Cultural competence	Student interviews on field trip effectiveness, quantitative quality ratings, cultural competence in post-program questionnaire; faculty observations
	Outreach to US K-12 students after the IRES experience	Frequency of school visits	Student interviews on outreach effectiveness, quantitative quality ratings in post-program questionnaire; faculty observations; students from outreach schools who apply to SDSU or CPP engineering programs
	Develop a program video for outreach	Quality of video	Student and faculty ratings

The primary measures fall into two general categories: research skills and psychological variables. The research skills measures include self-reported ratings of research confidence, and research skills such as identifying limitations of research methods and design, understanding of the theory and concepts guiding their research project, the ability to ask pertinent or insightful questions about complex issues, and formulating a testable research question. The psychological variables of interests are students' identification with becoming an engineer, their education and career intentions, their sense of belonging to the engineering community, and their comfort with diversity and cross-cultural exchanges.

Results

Pre- and post-departure evaluations. Interviewees indicated that the pre-program orientation provided them with adequate training in research ethics, lab safety, and research techniques to successfully start their individual projects in Durban. All participants indicated they learned a great deal about research in their projects including how to develop a sampling plan, how to process their samples, and how to report their results in professional presentations. During the process, participants applied their knowledge of research ethics and lab safety. For example, participants wore personal protective equipment and maintained a clean and organized laboratory space.

An analysis was computed comparing participants' self-reported research skills before starting the program (Pre) and after the program ended (Post). Paired samples *t*-tests indicated that participants ($N = 4$) reported greater research skills after completing the program, $t(3) = 1.94$, $p = 0.148$ ($M_{pre} = 3.34$, $SD_{pre} = 0.88$, $M_{post} = 3.75$, $SD_{post} = 0.57$). An analysis of each component of research skills indicated a gain in the ability to ask pertinent or insightful questions about complex issues, $t(3) = 3.00$, $p = 0.058$ ($M_{pre} = 3.00$, $SD_{pre} = 0.82$, $M_{post} = 3.75$, $SD_{post} = 0.96$); formulating a testable research question, $t(3) = 2.61$, $p = 0.08$ ($M_{pre} = 2.5$, $SD_{pre} = 1.29$, $M_{post} = 3.75$, $SD_{post} = 0.96$); understanding of the theory and concepts guiding their research project, $t(3) = 1.99$, $p = 0.141$ ($M_{pre} = 3.00$, $SD_{pre} = 1.41$, $M_{post} = 4.25$, $SD_{post} = 0.50$); and identifying limitations of research methods and designs, $t(3) = 2.45$, $p = 0.092$ ($M_{pre} = 2.75$, $SD_{pre} = 1.50$, $M_{post} = 3.75$, $SD_{post} = 0.96$). Many of the results are marginal or non-significant trends due to the small sample size of the first cohort. However, we report these trends because they are apparent even with a sample of only 4 students who completed both pre- and post-questionnaires. In subsequent years the larger sample size will likely yield statistically significant results.

A descriptive analysis was computed comparing participants' self-reported research accomplishments before starting the program (Pre) and after the program ended (Post). Frequencies were compared and indicated that participants ($N = 4$) reported greater research accomplishments after completing the program. Specifically, students were more likely to have: presented a talk or poster at a professional conference ($M_{pre} = 50\%$, $M_{post} = 75\%$); and wrote or co-wrote a paper published in an undergraduate research journal ($M_{pre} = 0\%$, $M_{post} = 25\%$).

Positive or negative feelings after the international research experience. Data from interviews indicated that the project was successful and that there were many more benefits than drawbacks in the program. Participants found it difficult to identify negative aspects of the program or areas for improvement. All participants reported very positive cultural experiences. At this time the survey data do not indicate significant changes from pre to post regarding comfort with cultural diversity. However, when the sample size is larger, we anticipate a significant increase in comfort with cultural diversity from pre- to post.

The post-program questionnaire indicated that participants ($N = 4$) found all aspects of the program in Durban valuable or very valuable. The following activities were rated as Very Valuable by all participants: the ice breaker, introduction to project goals, interactions with the research group leaders, the South Africa cultural experiences, and the program overall. The following activities were rated as Somewhat Valuable to Very Valuable by participants: the travel paperwork process, the homework assignments, interactions with graduate students, keeping notebooks/journals, the video conferences with the PIs, and the student presentations.

Identification as engineer and as researcher. An analysis was computed comparing participants' self-reported identity as an engineer before starting the program (Pre) and after the program ended (Post). Paired samples *t*-tests indicated that participants ($N = 4$) reported greater identification as an engineer after completing the program, $t(3) = 4.45$, $p = 0.092$ ($M_{pre} = 5.00$, $SD_{pre} = 0.82$, $M_{post} = 6.00$, $SD_{post} = 0.00$). All students strongly agreed with the statement "I am an engineer" after completing the program.

Motivation to pursue graduate school and careers related to environmental engineering. Participants were asked to describe how the experience has or has not changed their plans for (1) further education in engineering and (2) a career in the field of engineering. In response, participants reported new or strengthened interest in pursuing graduate education in engineering and careers in engineering. In particular, participants reported that they developed a new interest, or strengthened their existing interest, in working with wastewater related issues, and working with developing communities.

An analysis was computed comparing participants' intentions to pursue a career in Engineering before starting the program (Pre) and after the program ended (Post). Paired samples *t*-tests indicated that participants ($N = 4$) had stronger intentions to pursue a career in engineering after completing the program. Specifically participant reported greater intent to work as hard as necessary to achieve a career in engineering, $t(3) = 1.73$, $p = 0.182$ ($M_{pre} = 5.50$, $SD_{pre} = 0.58$, $M_{post} = 6.00$, $SD_{post} = 0.00$); and participants had higher expectations that a career in engineering will be very satisfying, $t(3) = 1.73$, $p = 0.182$ ($M_{pre} = 5.50$, $SD_{pre} = 0.58$, $M_{post} = 6.00$, $SD_{post} =0.00$).

Similarly, an analysis was computed comparing participants' intentions to pursue a PhD in Engineering before starting the program (Pre) and after the program ended (Post). Paired samples *t*-tests indicated that participants ($N = 4$) had stronger intentions to pursue a PhD in engineering after completing the program, $t(3) = 2.45$, $p = 0.092$ ($M_{pre} = 2.75$, $SD_{pre} = 1.5$, $M_{post} = 3.75$, $SD_{post} =1.26$). Many of the results are marginal or non-significant trends due to the small sample size of the first cohort.

Summer research outcomes. The project outputs of the first year program are still underway. A variety of activities were performed by the participants, such as technical presentation, projects, and dissemination activities. There were several basic requirements of the summer research: 1) a group presentation on the overall research experience delivered to UKZN students, scientists, and faculty before traveling back to the US, 2) a final report on each student's individual research project to be submitted shortly after return to the USA, 3) a poster summarizing the cohort's research results for presentation at conferences in the USA, 4) a video showing highlights of the experience to be used in educational outreach activities, and 5) educational outreach to K-12 students. These were intended to provide technical expertise and professional development for IRES participants (Table 1).

In preparation for the final group presentation at UKZN, the students had two opportunities to present their initial and intermediate results to UKZN collaborators. After their final group presentation at UKZN, IRES participants received feedback from UKZN faculty and students. Upon return to the USA, each student wrote a report detailing the findings of his/her individual research project. Raw and summary data files were also uploaded to an online resource for data sharing between all collaborators. Using the content of the five UKZN posters, the main results were compiled into one comprehensive poster that has been accepted for presentation in regional and international conferences In the fall of 2015, three IRES students led K-12 outreach activities through the SDSU Math Engineering and Science Achievement MESA Program by developing a water treatment hands-on activity for several local middle schools. One IRES student was an invited speaker of the California Water Environment Association (CWEA) student organization and shared research results and perspectives on cultural challenges and life experiences associated with the trip.

Recommendations to improve cohort 2 experience. Feedback from Cohort 1 indicated that there are several areas to consider for program improvement.

- **Workload**: Some participants suggested holding the pre-program orientation during an academic break to reduce workload. To further reduce workload, participants recommended involving UKZN undergraduate students as assistants and collaborators on the projects. Participants also wanted an additional week for data collection.
- **Leisure time**: Participants reported wanting more leisure time during the program. Some participants requested having three-day weekends to allow for more leisure time whereas others requested the option to stay an additional week or two after the research project ends.
- **Orientation**: Some participants recommended additional lessons in the orientation including data analysis training specific to the projects, discussion of different leadership styles and working in teams, and discussing education and research funding opportunities for students.
- Independently from the IRES Cohort 1 participants' feedback, to expand the program impact and to enhance future IRES participants' experience, the PRG collaborators recommended to have UKZN undergraduate students partner with each of the IRES cohort 2 participants. Additionally, to ensure that the program includes students with a variety of skills PRG scientists are part of the committee that evaluates and ranks the student applications. At this moment IRES cohort 2 applications are under evaluation and later in Spring 2016 the remaining portions of the program will be reviewed.

Conclusion

The IRES program first-year evaluation indicates that the international research experiences led participants to experience greater research self-efficacy and positive attitudes toward science and environmental engineering. Additionally, participants reported greater desire to pursue a higher degree in engineering and careers in engineering. Moreover, the connections to societal needs and engineering challenges faced in Durban have produced a transformative cultural experience that resulted in positive impacts on each student and enhanced the global engineering curriculum component in both CSU campuses.

Acknowledgements

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Stress Analysis of a Disk Subjected to Diametrical Compression by Using a Reflection Polariscope

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Abstract
Stress analysis is a highly theoretical and conceptual topic. Some of the topics which are covered in a course in stress analysis are too abstract for students to fully comprehend the theory. This paper describes how a reflection polariscope was used to help students visualize and understand stresses in a stressed body. A reflection polariscope is an optical instrument that creates full-field fringe patterns on a stressed body. These fringe patterns help students visualize the complete distribution of stresses on the surface of the structure. The body which was selected for stress analysis in this investigation was a disk subjected to diametrical compression. The disk was made of 6061-T6 aluminum with a diameter of 2.5 inches and a thickness of 0.25 inches. The surface of the disk was covered with a reflective coating and a birefringent material with a thickness of 0.122 inches. The disk was loaded diametrically by a compressive force of up to 3,000 pounds and was viewed with a reflection polariscope and a CCD camera. The isochromatic fringe patterns which were created on the surface of the disk represent contours of points with constant maximum shear stress values. Bands with different colors, which were created on the surface of the disk, help students visualize the stress distribution over the stressed body. These fringes were used to plot contours of maximum shear stress. In addition, a video was created that shows the formation and motion of fringes during the loading and unloading of the disk. Starting with the unloaded disk, the video shows the fringes appearing at the most highly stressed points (contact points). As the load was increased, new fringes appeared, pushing the earlier fringes toward the areas of lower stress. Seeing the stress distribution on the structure will help students learn the theories of stress analysis more effectively. Using the new technology, students can instantly identify critical areas and see the overstressed and understressed regions in a structure. Experimental results were compared with the analytical results from the theory of elasticity. Both results are in good agreement (within 5-10 percent error), and show that maximum stresses occur at the points of contact. In addition, stress patterns and videos will be used in other courses for visualization or verification purposes. In the Finite Element Analysis (FEA) course, students will use the stress patterns for verification and validation of their FEA results.

Introduction

Stress analysis or 'mechanical design' as it is sometimes called, is a junior or senior level course where students gain a working knowledge of how to design and analyze machine components and structures. Some of the topics in this course are difficult for students to comprehend. This is evidenced from the fact that the rate of failure in this class is usually very high, in the order of 30 to 50 percent or more. The purpose of using a polariscope was to help students learn some of the theories covered in this course by visualizing the stresses acting on a stressed body. For this purpose, a disk subjected to diametrical compression was selected for stress analysis. This selection was made because analytical solution of this problem from the theory of elasticity already exists. By using the reflection polariscope, students can visualize the stress distribution on the disk and compare them with the analytical solution. In addition, students can visualize the low stress regions, as well as the high stress regions which are at the points of contact.

Specification of the Disk

The disk was made of 6061-T6 aluminum with a diameter of 2.5 inches and a thickness of 0.25 inches. Surface of the disk was coated with a reflective adhesive (PC-10 Adhesive 80-GM, Vishay Measurements Group, Micro-Measurements, Part number MMF016953), and a birefringent material with a thickness of 0.122 inches (PS-1A Sheet Material 10 X 10 X 0.12, Vishay Measurements Group, Micro-Measurements, Part number MMF016993). The birefringent material was bonded to the surface of the disk by using the reflective adhesive. Figure 1 shows the disk with the reflective coating, covered with the birefringent material. The disk was placed in between the platens of an Instron 3360 Load Frame machine with Bluehill 2 Testing Software, and was subjected to diametrical compressive forces of up to 2,600 pounds.

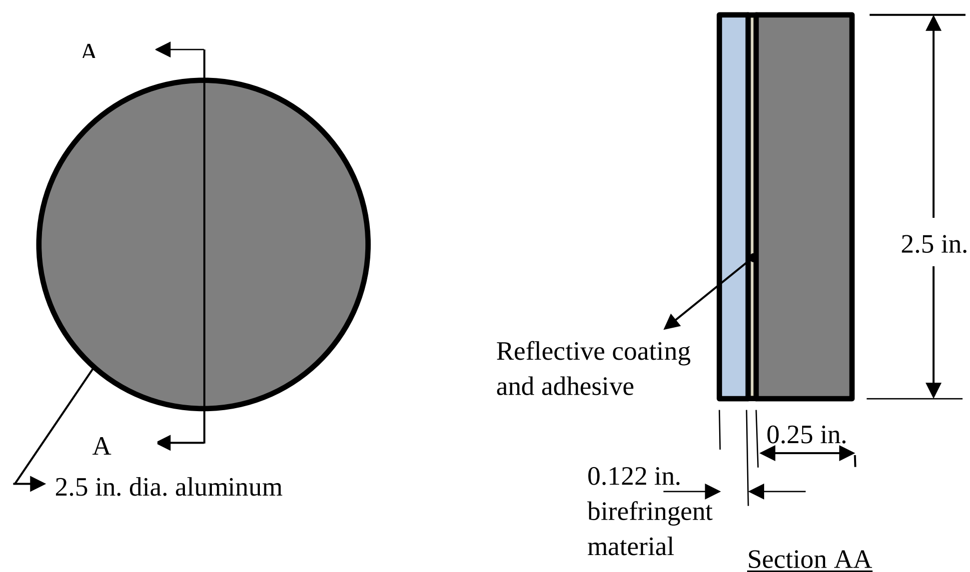


Figure 1. Aluminum disk coated with reflective adhesive and covered with birefringent material

Reflection Polariscope

A reflection polariscope is a device which can be used for full-field stress and strain analysis (Dally, 1991). It is an extension of photoelasticity procedures which can be used to determine surface stresses in two and three dimensional bodies. Unlike in photoelasticity where a model made of photoelastic material is needed and light passes through the model, in a reflection polariscope, the birefringent material is directly applied to the prototype and the need for models is eliminated. As a result, in a reflection polariscope, light is reflected by the reflective coating applied at the interface of the prototype and the birefringent material. The basic elements of a reflection polariscope are shown in Figure 2. It consists of four optical elements and a light source. The four optical elements are: (1) a linear polarizer closest to the light source called the polarizer, (2) a quarter-wave plate with its axes set at 45^{o} with respect to the axes of the polarizer, (3) a second quarter wave-plate set with its fast axis parallel to the slow axis of the first quarter-wave plate, and (4) the analyzer which is a linear polarizer with its axis of polarization perpendicular to the axis of polarization of the polarizer. The light source used is a standard incandescent white light. The reflection polariscope which was used in this investigation was PhotoStress Plus System (V) from Vishay Measurements Group, Micro-Measurements, Part number MMP920-000308. Figure 3 shows the isochromatic fringe patterns which were created and viewed by the camera when the disk was subjected to a compressive force of 2,600 pounds.

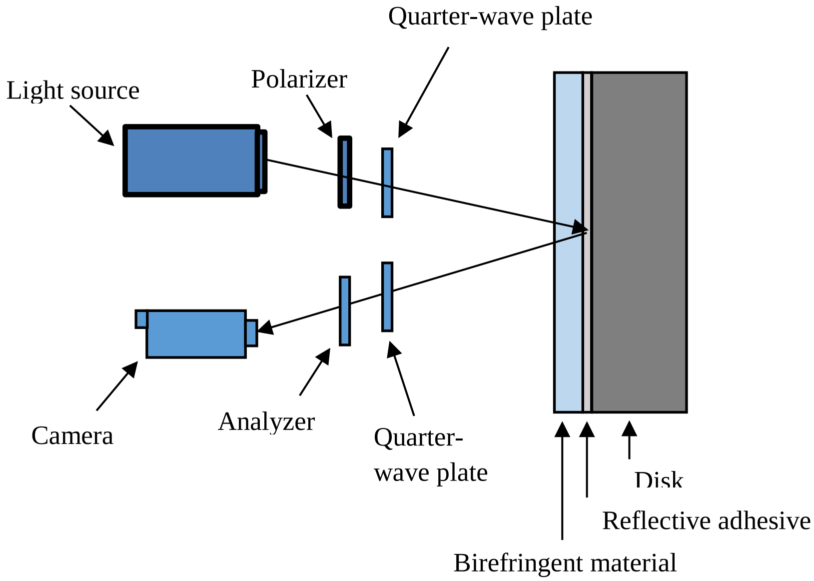


Figure 2. Schematic representation of the reflection polariscope used to measure stresses on the disc

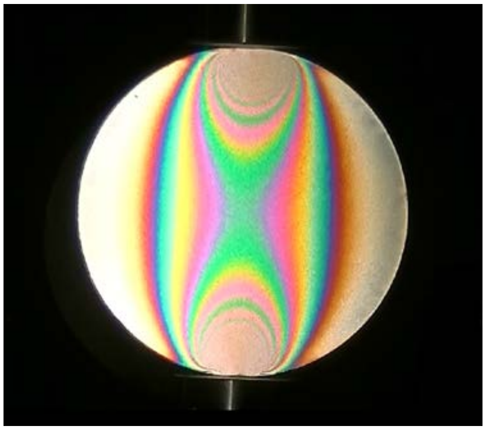


Figure 3. Isochromatic photoelastic fringe patterns for a disk subjected to diametrical compression

Colored bands in the Figure represent points with constant difference in their principal stresses. The difference in the principal stresses σ_1 and σ_2 is given by (Dally 1991):

$$\sigma_1 - \sigma_2 = \frac{N f_\sigma}{h} \tag{1}$$

or,

$$\tau_{max} = \frac{\sigma_1 - \sigma_2}{2} = \frac{N f_\sigma}{2h} \tag{2}$$

Where *N* is the fringe order, f_σ is the photoelastic material fringe value, and *h* is the thickness of the disk. Measuring *N* which is based on the color and position of the fringe, and establishing the material fringe value f_σ by calibration, the difference in the principal stresses can be determined at any point on the disk.

Photoelastic Material Calibration

Calibration was done by using the center point of the disk. The material fringe value $f_{\boldsymbol{\sigma}}$ that is necessary to accurately determine the stress distribution in a model using photoelastic analyses varies with the supplier, age, and temperature. Thus, it is necessary to carefully calibrate each sheet of photoelastic material at the same time that the test is performed. To this end, the model was loaded in increments and the fringe order was recorded using the null-balance compensator provided with the LF/Z-2 Reflection Polariscope. Using the equations from the theory of elasticity (Dally 1991), for a circular disk subjected to a diametrical compressive load P, the stress distribution along the horizontal diameter can be determined by using the following equations, where D is the disk diameter, *h* is the disk thickness, and *x* is the horizontal distance from the center of the disk.

$$\sigma_{xx} = \sigma_1 = \frac{2P}{\pi h d}\left(\frac{D^2 - 4x^2}{D^2 + 4x^2}\right)^2 \tag{3}$$

$$\sigma_{yy} = \sigma_2 = -\frac{2P}{\pi h d}\left[\frac{4D^4}{(D^2 + 4x^2)^2} - 1\right] \tag{4}$$

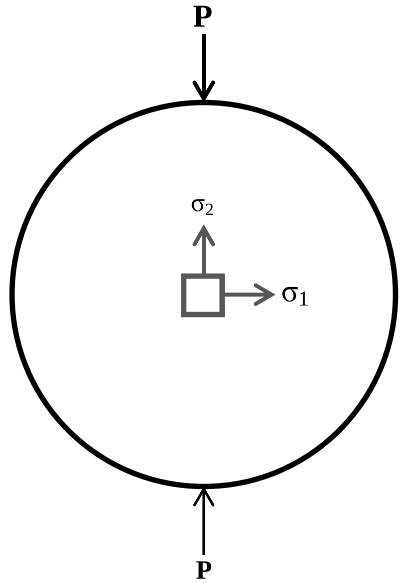


Figure 4. State of stress at the center of the disk which was used for calibration

From this, the difference in principal stresses (σ_1 and σ_2) can be determined to be

$$\sigma_1 - \sigma_2 = \frac{8P}{\pi h D}\left[\frac{D^4 - 4D^2x^2}{(D^2 + 4x^2)^2}\right] = \frac{Nf_\sigma}{h} \tag{5}$$

Or by isolating the material fringe value,

$$f_\sigma = \frac{8P}{\pi D N}\left[\frac{D^4 - 4D^2x^2}{(D^2 + 4x^2)^2}\right] \tag{6}$$

where N is the fringe order.
In this case, however, the center of the disk was used to calibrate the material such that $x = y = 0$, with several loads being applied to the model. In this manner, the equation above for f_σ reduces to

$$f_\sigma = \frac{8}{\pi D}\left(\frac{P}{N}\right) \tag{7}$$

The null-balance compensator is a precision calibrated device that can be manually adjusted to optically superimpose an equal but opposite sign color over that which exists at the measurement point on the loaded test part. To measure the fringe order, the compensator control knob was adjusted until a black band superimposed the fringe at the center of the disk.

Table 1 displays the recorded data for the fringe order N (the compensator reading, taken at the center of the disk) at various loads. The plotted data (Figure 5) displays a linear relationship between load and fringe order, the slope of which is used to calculate the material constant, f_{σ}.

Table 9: Calibration Data

Load, P (lbs)	**Fringe Order, N**
1645	1.08
1917	1.27
2175	1.44
2320	1.55
2504	1.67
2790	1.89
3060	2.1

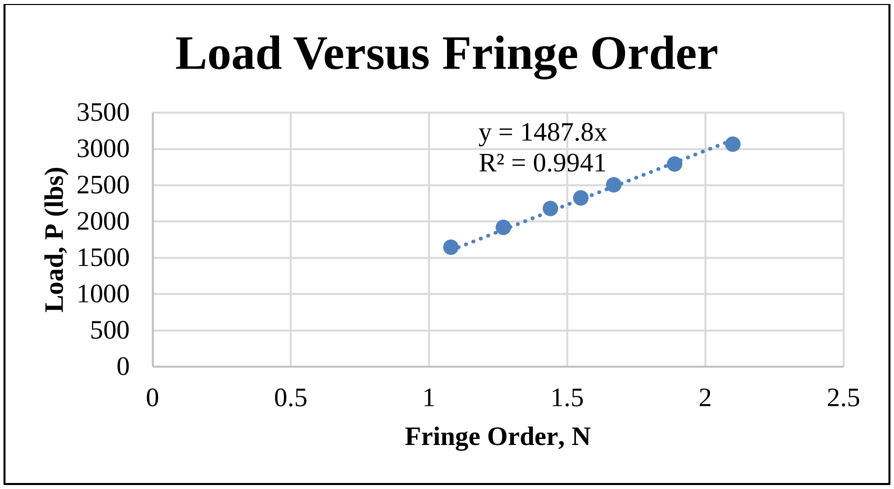
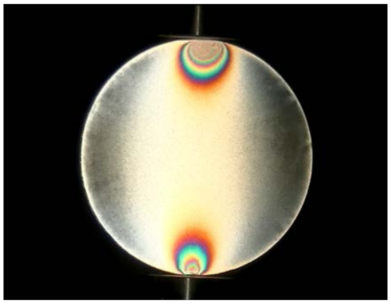
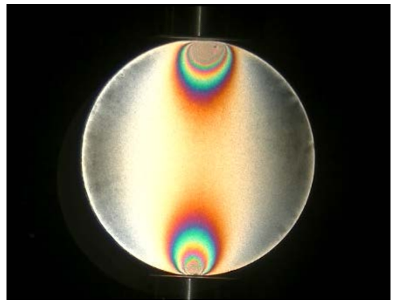


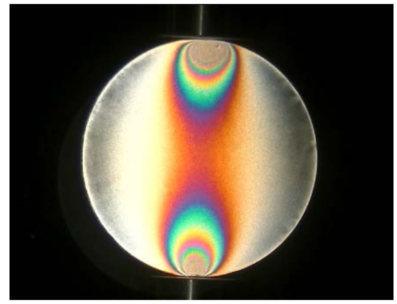
Figure 5. Photoelastic material calibration curve

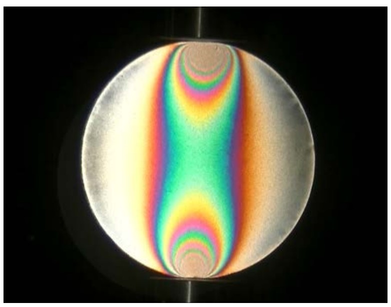
Experimental Results

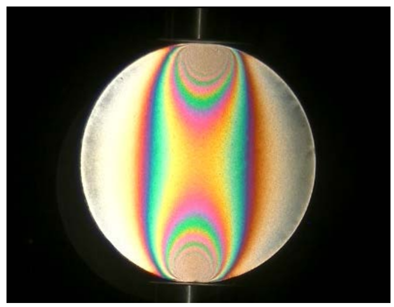
Figure 6 shows the isochromatic fringe patterns at various loads. As the load was increased from zero, fringes first appeared at high stressed regions. As load was increased, new fringes appeared, and earlier fringes were pushed toward lower stress areas. A video was created which shows the complete creation of new fringes, as well as their movements toward low stress regions of the disk.


Fringes at 500 lbs


Fringes at 750 lbs


Fringes at 1000 lbs


Fringes at 1500 lbs


Fringes at 2000 lbs

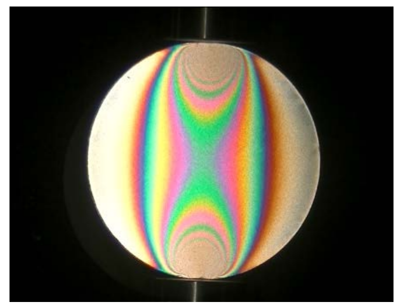

Fringes at 2500 lbs

Figure 6. Isochromatic fringe patterns at various load levels

Figure 7 shows the fringe orders at 2,000 pounds along the horizontal diameter of the disk. Fringe orders range from 0.3 corresponding to low stress regions, and increase to 1.3 at the center of the disk, which is the high stress area. These fringe orders were used in equation (2) to calculate the shear stresses which are shown in Figure 8. This Figure compares the shear stresses obtained from the reflection polariscope to the stresses from the theory of elasticity. The experimental values of shear stresses are about 5 to 10 percent less than the theory of elasticity values. The error may be due to the calibration of the photoelastic material or due to readings of the fringe orders from the compensator.

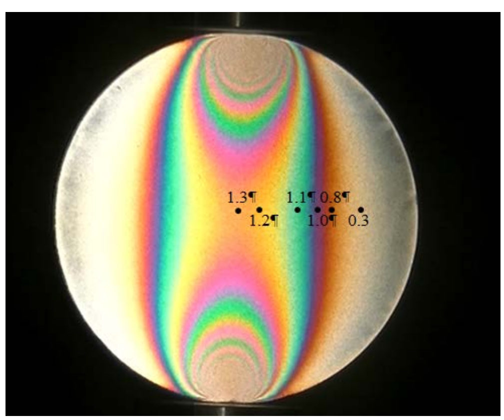


Figure 7. Fringe orders corresponding to a compressive force of 2,000 pounds

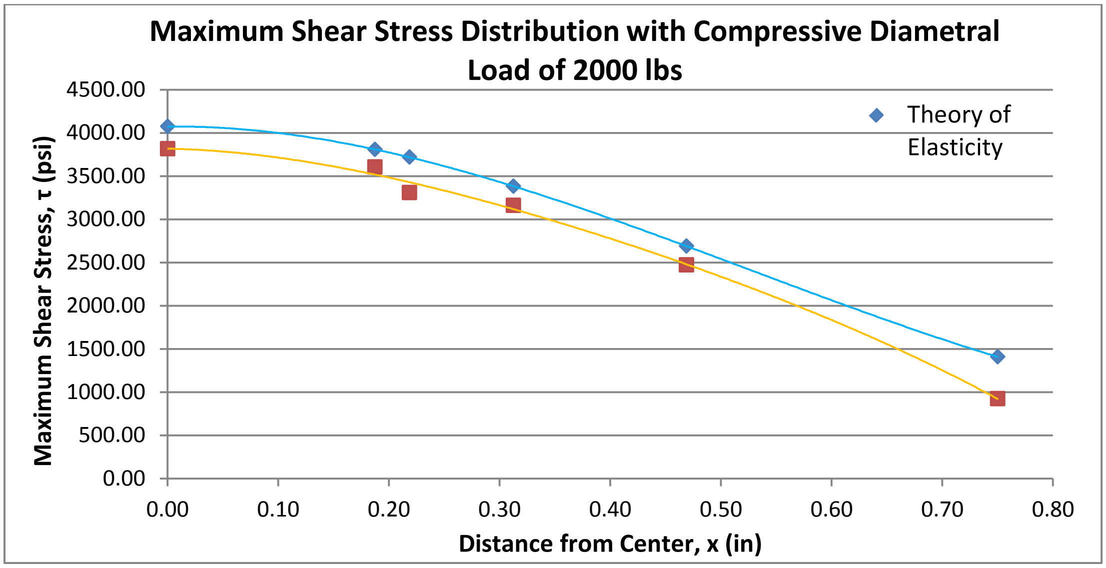


Figure 8. Graphs of shear stresses from the reflection polariscope and the theory of elasticity

Conclusions

Preliminary feedback from the students and the faculty at Cal Poly Pomona shows that visualization of stresses are helpful for many students in learning some of the topics in a course in stress analysis. This is true, especially as most of the students are visual learners. The majority of students like to see pictures, diagrams, videos, and animations. The reflection polariscope will help those students. In addition, those students who prefer to see practical applications rather than abstract theory will benefit from using the polariscope. Results from the reflection polariscope were in good agreement with the results from the theory of elasticity. The error in the shear stress values were between 5 and 10 percent. This may have been due to errors in the calibration process or readings of the fringe orders.

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The Bumblebee: A Robot Controller Board for STEM Education

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Abstract
This paper provides a case study description of the Bumblebee robot controller. We designed the Bumblebee as a controller board that provides hardware and software support for elementary aged students interested in building robots and learning about electronics. When teaching elementary aged students, one is often limited to a selection between Arduino type hardware and LEGO Mindstorms kits. Arduino hardware can be limiting for a new student because the boards are not tolerant of wiring errors. LEGO Mindstorms kits can be prohibitively expensive and can be limiting in the number of sensors that can be attached. The hardware for the Bumblebee is designed to allow interfacing with readily available Arduino shields while providing more usability features such as an LCD screen. One of the important aspects of the Bumblebee controller is fault tolerance. Students can make several different types of connection errors and the board will handle these faults without damage. Buzz is a companion programming language that is designed for elementary age students to easily program the board. We developed a front-end preprocessor that takes in Buzz code and converts the source into C which can be compiled with available compilers. We find that the Bumblebee is suited for university level instruction as well. The fault tolerant aspects are extremely practical and we allow students to program the boards in C. This board was successfully used in a university-level robotics class this Fall 2015 and we outline the experience. We have tested the Bumblebee with elementary-aged students in workshop type environments and find that the opportunity to use a breadboard and build electrical circuits keeps the students highly engaged and excited to learn.

Introduction

Robotics and electronics are excellent motivators for teaching engineering principles to students. The excitement of seeing something move or seeing a circuit function encourages students to learn more about these fields. Elementary school children in particular have interests in these areas, but some readily available options may be technically challenging for their age group or may be cost prohibitive. In this work, we describe the development of the Bumblebee controller board. The Bumblebee board is designed for elementary-aged students to build robotics and electronics projects. This age group requires a board that is easy to program, has simple connectors, is tolerant of wiring faults, and can easily run on batteries. This paper is organized as follows. We first describe work that is related to the Bumblebee board in both the hardware design and in software capabilities. Next, the hardware details of the board are covered as well as some of the differences between the readily available Arduino Uno platform. The software overview section describes the Buzz programming language that has been developed for the Bumblebee. Finally, we describe the testing experiences we have in using the Bumblebee with elementary school students and college students as well.

Related Work

The Bumblebee board falls into the class of 8-bit microcontroller boards that has been greatly popularized by the Arduino Uno and derivatives. These boards are commonly based on the Atmel AVR architecture. Some boards that have been introduced over the past few years which are intended for robot designs include the Digilent chipKIT Mx3 (Digilent, 2016) and the Sparkfun RedBoard (Sparkfun, 2016). The Bumblebee is most similar to the MIT HandyBoard (Martin, 2001) which featured an on-board LCD display, on-board motor drivers, and a pre-built software library.

The fault tolerant design of the Bumblebee is similar in spirit with the commercial Ruggeduino (Rugged Circuits, 2016). The Ruggeduino is an Arduino Uno compatible design which builds in many fault tolerant aspects to prevent damage due to user error. The Buzz programming language and the Lego Mindstorms kit (Lego, 2016; Hixon, 2007) fulfill the same niche of robotics programming directed at a younger audience. The Lego Mindstorms kit uses graphical blocks in a drag-and-drop fashion to allow students to build their program. Unlike the Buzz language however, the Mindstorms kit is not based on event-based programming. There does not exist an explicit loop that runs forever or triggers that activate when programmed conditions are met. The Mindstorms kit can also be prohibitively expensive for schools operating on a low budget with large classes.

Other efforts to encourage younger students to program include the free programming language Scratch (Maloney et al., 2010). Scratch also uses color coded blocks that students drag-and-drop to create their programs. To provide feedback to the users, instead of controlling a robot, the student manipulates sprites in a window and watches them move. Buzz on the other hand emphasizes textual code programming instead of drag-and-drop style programming. In contrast to a computer graphic, students will be able to control the Bumblebee board coupled with circuitry or robot hardware, allowing a tangible experience of the actual consequences of their code.

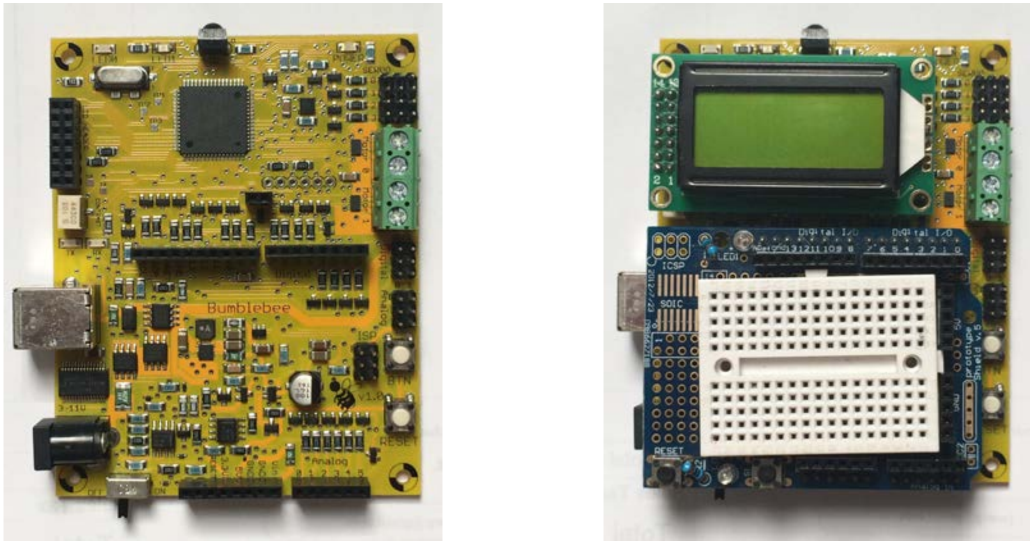


Figure 1: Bare Bumblebee board (left), Bumblebee with LCD and breadboard shield (right)

Hardware Overview
The hardware design philosophy of the Bumblebee was to create an Arduino shield-compatible board that could easily integrate with existing robot hardware. The target audience was elementary school students, so the hardware needed to be tolerant of wiring faults, operate at a low voltage, and require minimal configuration. In this section of the paper, we list the hardware features and implementation details.

Hardware Features. The hardware functionality of the Bumblebee is listed below:

- Arduino Uno shield compatible
- Removable 2 line by 8 character backlit LCD
- 2 DC motor ports (1.8A maximum current each)
- 4 RC servo ports
- 3-axis accelerometer
- IR receiver for decoding remote control signals
- 16MHz Atmel ATmega645A (64KB flash, 4KB RAM)
- 2 software-controlled LEDs
- 1 user pushbutton
- DC power jack (3V to 11V)
- On/off switch

Advantages over Arduino. The standard Arduino Uno (Arduino, 2013), though low cost, has a number of disadvantages when used to teach basic electronics, embedded systems, or robotics (Jamieson, 2010). Firstly, an Arduino requires an input voltage of at least 7V. This voltage requirement arises from the use of a regulator chip which requires input of at least 2V more than the regulated output of 5V. Because of this requirement, there are many classroom assignments which specify that a separate battery, most often a 9V, is required to power the Arduino while another battery is used to power other devices, such as 4xAA batteries for motors or servos. This 2 battery requirement can be complicated for students to understand and furthermore complicates the overall wiring. The Bumblebee has a voltage input range which extends down to 3V. This allows the board and motors to be powered by 2xAA batteries if necessary while still providing 5V to the other parts of the board.

Secondly, the Arduino maps the first pair of primary digital pins, pins 0 and 1, to the wires that are used in the firmware uploading process. This default mapping often confuses students because the Arduino will often fail during upload operations if there are any sensors or devices connected to digital pins 0 and 1. Students have to temporarily disconnect devices, perform the upload, and then reconnect the devices to test. This process can be cumbersome when uploading firmware to the Arduino. Because the Bumblebee uses a dedicated set of pins for the upload communication, there is no contention issue over those pins. Thirdly, a major advantage of the Bumblebee over the Arduino is fault tolerance. As part of the learning process, students may incorrectly wire a circuit which can easily damage an I/O pin on an Arduino. Wiring faults such as shorting power to ground or shorting digital I/O pins to ground are common. The Bumblebee is designed to tolerate incorrect wiring of the I/O pins and this allows instructors and students to focus on learning about circuits without worrying about damaging the boards.

Firmware. The Bumblebee uses a modified version of the Optiboot (Optiboot, 2016) bootloader. This is an open source bootloader and is an alternative to the original Arduino bootloader. This bootloader is Arduino compatible and is flashed onto the primary microcontroller before the board can be used. Modifications to the stock Optiboot bootloader include a built-in testing mode which the user can run regardless of the current state of the user-flashed program. This testing mode allows testing of the inputs, motors, servos, and battery voltage. Testing mode is enabled by holding down the user button while pressing and releasing the reset button.

Hardware Prototyping. The initial funding for the development of the Bumblebee was supported by an internal Cal Poly grant. This grant was used to build a few initial prototypes and eventually the funds were used to do a bulk build of 100 boards.

Software Overview

Programs for Arduino compatible boards, such as Bumblebee, are typically written in the C programming language. With elementary school students as the target audience, we explicitly expect that this audience will not have prior programming experience. The low-level nature of the C programming language coupled with the conceptual overhead of learning both the hardware and software aspects of working with Bumblebee prompted the exploration of alternatives. The outcome of this exploration is the design and implementation of an alternate development language, named Buzz, to support the introduction of robotics programming to elementary school students.

Buzz Programming Language. Buzz is a programming language geared towards elementary school students and is designed for programming in an event-based model. Buzz features a more natural English-based syntax with less syntactic complexity than C. The event-based model allows students to write code segments to react to external stimuli (button presses, updated sensor data, clock ticks, etc.); this style of asynchronous programming allows the student to focus on which actions to take in response to events without concern for the overhead of polling for changes, checking against previous values (for updates), and triggering code. Buzz programs are textual. The language design intentionally eschewed a drag-and-drop graphical model, like that used in the LEGO Mindstorms kit, to reinforce the link between instructions (even at the high-level of Buzz) in the program and operations by the robot. Instead, the syntax of Buzz mimics that of Python to reduce syntactic overhead and uses English-language like keywords to help children leverage their familiarity with a natural language in understanding the programming language. This decision was made to help abstract out C concepts that would be confusing and difficult for students to learn when first trying to grasp programming. The Bumblebee supports, in its default configuration, the following devices: RC servo motors, DC motors, analog sensors, digital sensors, and an on-board button. Some of these devices are write-only (e.g., servo motors and DC motors) and some are read-only (e.g., the analog sensors and the button). For each device, an appropriate set or get keyword is automatically provided by Buzz to support (e.g., setting a voltage or reading an input value).

```
define thermometer = analogPinIn[0]
define leftServo = servo[0]
define rightServo = servo[1]

when start {
  display "Hello! Machine is starting up"
}

repeat {
  display "Thermometer reading is: " + get thermometer
  set leftServo 15
  set rightServo 75

  display "Temperature in Celsius is: " + ((get thermometer - 32) * 5 / 9)
}
```

Figure 2: Sample Buzz program

Figure 2 illustrates the layout of a basic event-driven Buzz program. This program begins by giving names to different devices and continues with the two most basic event handlers. The first, ‘when start’, executes once when the program begins while the second, ‘repeat’, executes repeatedly for the duration of the program. Within these handlers are examples of simple statements to display text to the screen, to set the servos, and to get thermometer readings. Figure 3 presents a longer program with examples of more complicated event handling. This example illustrates the use of variables, the definition and invocation of functions, and different forms of event handlers including conditional checks and a general ‘changes’ check.

```
define tL = motor[0]
define tR = motor[1]

define thermometer = analogPinIn[0]

define gX = gyroscope[X]
define gY = gyroscope[Y]
define gZ = gyroscope[Z]

variable storedTemp = 0

func turnRight() {
  set tL 60
  set tR 30
  return 0
}

func halt() {
  set tL 0
  set tR 0
  return 0
}

func go() {
  set tL 70
  set tR 70
  return 0
}

when get thermometer > 15 {
  halt()
}

when get gX > 100 and get gY > 100 {
  display "Both X and Y > 100"
}

when thermometer changes {
   if get thermometer < storedTemp {
      turnRight()
   }
   storedTemp = get thermometer
}

when get button equals 1 {
  stop
}

go()

repeat {
}
```

Figure 3: Longer Buzz program example. Execution starts from the top.

Development Environment. To aid the novice programmer, the jEdit (jEdit, 2016) programming text editor has been extended with support for the Buzz programming language. jEdit is written in Java, is open source, and contains a plugin architecture which allows different enhancement modules to be written for the editor.

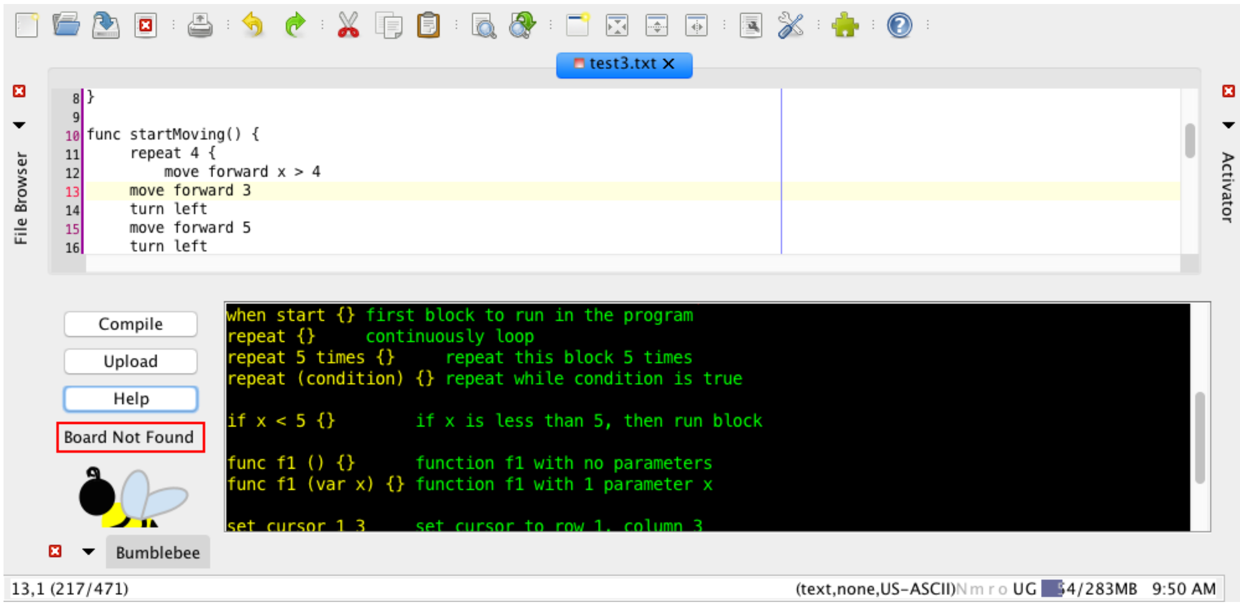
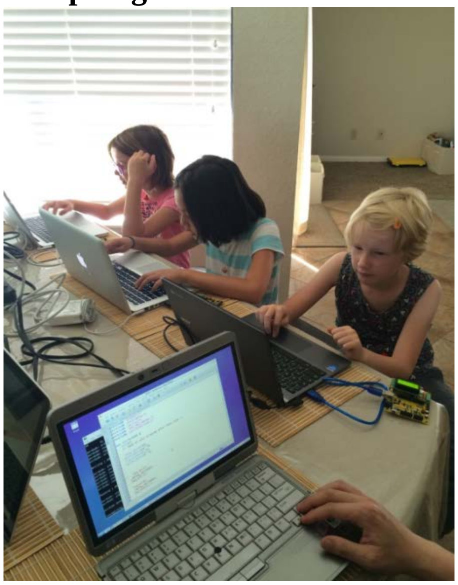


Figure 4: Example jEdit screen with Buzz plugin

The Buzz plugin that we added has features that allow younger students to immediately see what is wrong in their code or their setup of the system. This plugin is shown in Figure 4. There is a "Board Not Found" field with a red border when a board is not properly attached to the computer. The text of this field changes to "Board Found" and the border changes to green when the board is properly attached. For those new to Buzz, there is a *Help* button that will display example code in the output window; this example demonstrates the language syntax and shows how to set up some of the available devices. The *Compile* button will run the Buzz compiler on the current program. While compiling, if there are errors, the corresponding line number and error explanation are displayed. If there are no problems with the code, then an explicit "No errors" message is displayed (to avoid the "did it do anything" question common with "succeed silently" compilers). This compilation phase also automatically invokes the C compiler to generate an executable that can then be uploaded to the Bumblebee board, thus hiding this detail from the user. The *Upload* button will flash the executable to the Bumblebee board.

Transpiling to C




The Buzz programming language is not, of course, natively supported by the Bumblebee board. The Buzz compiler is actually a Java transpiler that translates the given Buzz program into an equivalent C program leveraging support from a firmware library used to provide a convenient interface with the various devices attached to the Bumblebee board. This translation approach simplifies the development and maintenance of the Buzz compiler and allows Buzz programs to be linked against C libraries during the second (C) compilation step.

Error Checking. Beginning programmers often make syntax mistakes and thus, must contend with compiler errors. Even with the simplified syntax of Buzz, students will undoubtedly make typing mistakes or syntax errors. Though the GCC compiler front-end performs a thorough sweep of the code to ensure syntactic correctness, the error messages produced are not suitable for an elementary school student. For example, in C, if a variable declaration does not end with a semicolon, GCC will output a complex error message.

The Buzz compiler reports more direct error messages about what is missing or incorrect with the syntax. An example of such is: Identifier name of mach already taken [Line 3]. Though, at present, one shortcoming of the Buzz compiler is that it will only report at most one error, unlike the gcc compiler which can recover from a syntax error and continue reporting errors in other areas of code. Though this limitation might be considered unacceptable for experienced programmers, in the context of an elementary school activity the one-error-at-a-time model is less intimidating and avoids spurious cascading error messages.

Classroom Experience

The Bumblebee was first tested with elementary school-aged children in the Summer of 2015. This initial deployment of the board was through small summer workshops which consisted of groups of 4-6 students. Each three-hour session consisted of a student working on their own with a laptop and a Bumblebee board plugged into the USB port. In these sessions, we used the board only and did not use a robot base. The session involved a mix of programming in Buzz and C.

The students were first taught how to use the LCD. The LCD consists of 2 lines with 8 maximum characters on each line. Students were instructed on how to move the cursor on the screen, clear the screen, and how to print out messages. Students were also introduced to the concept of time delays in a program. Additionally, a breadboard shield was plugged into the Bumblebee allowing the students to plug wires directly to the board. This allowed the students to wire LEDs directly to individual digital I/O pins. Once the LEDs were connected through the breadboard, programs were written to flash the LEDs at various rates and patterns.

In Fall 2015, the Bumblebee board was used as the primary controller for a college-level introduction to robotics course. The board was coupled with an Ardbot II (Budget Robotics, 2016) robot which is a small robot platform that does not come with a controller. In this course, the students were expected to program in C using a pre-built Bumblebee C library. Students connected individual sensors to the board using either the analog or digital inputs. The robots were motorized using the servos outputs on the board. Assignments in the course involved activities such as line following, implementing a basic neural network similar to Imberman (2003), and Monte Carlo Localization (Dellaert, 1999). The class consisted of students using 18 Bumblebee boards and there were no board failures due to wiring or electrical faults.

Future Work

Future work for the Bumblebee board consists of software work since the hardware design is functional. In terms of IDE development, the jEdit plugin is functional, but the installation procedure requires installing several dependencies and the overall process could be streamlined and automated. In addition, the jEdit plugin can be improved upon to provide even friendlier compiler errors, warnings, and locations of each.

Although the Bumblebee pinout is designed to be Arduino compatible, it is compatible in terms of physical and electrical specifications, but not at the microcontroller software level. The Arduino Uno uses a different microcontroller with a different pinout from the microcontroller on the Bumblebee. That means that in order to function with particular existing Arduino shields, currently software libraries need to be modified. This future work would be necessary on a per shield basis.

Conclusion

The Bumblebee is an embedded controller board that is designed to teach programming and engineering concepts to elementary school students. We have found the board to be an effective and inexpensive teaching tool for younger students and for university students as well. The board hardware is designed with features that make it easier to use in the classroom environment. The Bumblebee circuitry is tolerant of wiring faults and is designed to operate from a low voltage battery. A built-in port to connect to commodity LCD displays makes debugging easier and provides visual feedback to students. In addition to C, the board can be programmed in the Buzz programming language. This programming language supports a simplified syntax and an event-based execution model. Together with the Buzz programming language and the Bumblebee hardware, this platform provides a versatile environment for students to learn about electronics and robotics.

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Comparing Cooperative Learning in Online & In-Person Versions of a Microprocessors Course

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Abstract
In this paper, we compare the in-person and online versions of a Microprocessors course. The course applies a project-centric, cooperative learning pedagogy, and thus the comparison provides valuable insight on the potential for adapting these active learning pedagogies to an online setting. Specifically, we analyze data collected on various course outcomes, and compare the grade distributions for individual and teamwork components of the student grades. We describe the trends observed in the data, and discuss the possible reasons behind these trends. Both courses were offered for credit as part of a BS degree program in Software Engineering. Throughout this paper, we highlight the issues faced in adopting project-based cooperative learning, so as to inform the design and implementation of cooperative learning in other online software engineering and computing programs.

Introduction

Motivation. Online learning has long been advertised as a mechanism for providing access to world-class education for communities and sections of society that might otherwise find it difficult to find such access in traditional learning institutions. However, the difference between what is advertised, or what proponents of online learning hope to achieve, and what is actually achieved, can be tremendous. Courses and degree programs in computer science, information technology, and software engineering are of special interest in the context of online education, as these are considered more amenable to online delivery. They are perceived to not need laboratories or other physical resources, and since these majors study computing they should not offer resistance to the delivery modality. Furthermore, out of all the STEM disciplines, CS, IT and Software Engineering are projected to have very strong growth in the number of jobs (Bureau of Labor Statistics, 2016). These factors taken together create the perception that not only is there a significant need for providing these skills to a large populace, but there is also a convenient and scalable medium for meeting this need, by implementing these programs online. However, the existing pedagogical methods that are deemed best for teaching and learning in in-person settings may or may not translate well to online teaching and learning.

Indeed, although a body of knowledge exists on teaching and learning online (Allen, Bourhis, Burrell & Mabry, 2002; Bernard et al., 2004; Ko & Rossen, 2010; Ku, Tseng, & Akarasriworn, 2013), researchers (Means, Bakia, & Murphy, 2014) are discovering that different aspects of online learning need to be explored in more detail within specific contexts for specific types of learners. Means et al. (2014) state that solid empirical research on implementations of online learning is limited, and is lagging behind technological innovations that act as game-changers.

They have specifically identified a need for moving away from broad claims about the benefits of online education, and focus on rigorous research performed in specific contexts, to test the aspects that provide additional advantages to students. This research project, and this paper in particular, is thus motivated by the need for testing the effectiveness of educational and pedagogical strategies for online education, and the absence of relevant research in the particular context of degree-granting online programs in CS, IT and Software Engineering. In particular, there seems to be a gap in the research literature for cooperative and project-based learning in the context of for-credit online classes.

Hypothesis and Research Question

The hypothesis is that teamwork and projects designed for an in-person course do not translate well to the online medium. The research question we ask is, "How well do activities and projects designed for an in-person cooperative project-based learning translate to an online class?" From this, we hope to inform the design and implementation of cooperative learning in other online software engineering and CS programs.

Microprocessor Course Description

Active Learning in the Microprocessors Course. The Microprocessors course incorporates a project-based (Prince, 2004; Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991) cooperative learning (Smith, Johnson, & Johnson, 1981; Smith, Sheppard, Johnson, & Johnson 2005; Johnson, Johnson, Roseth, & Shin, 2014) pedagogical approach, and relies on team-based course projects as the centerpiece for learning and assessment. The projects are based on assembly programming using the Progressive Learning Platform (PLP) (PLP, 2016). While PLP is multi-faceted, the aspect used in the microprocessor course is PLPTool, a platform-agnostic, stand-alone tool that students installed on their laptops. PLPTool helps in visualizing the execution of the assembly on the simulated architecture and acts as IDE and simulator with full debugging capabilities. It has been shown to be effective for teaching computer architecture and organization courses (Damron, Sohoni, Cho, & Kearney, 2013; Mulia, Fritz, Sohoni, Kearney, & Mwavita, 2013; Kearney, Damron, & Sohoni, 2015). A total of five projects accounted for 75% of the course grade.

Project 0 was a brief introduction to Git, a popular revision control system, which students were required to use when working in teams. In this project, students completed a tutorial and shared the Git repository with graders. During later team-based projects, students were expected to make regular commits of their code to their shared Git repository and share this repository with graders. This was done to add accountability for individuals and ensure that students could work from a shared code base.

Project 1 had the students build a simple calculator, which required the use of control flow and basic input from switches. The goal was to introduce students to the instruction set and the tool used for programming in assembly, and was done as an individual project.

Project 2 had students build a driver for a universal asynchronous receiver/transmitter (UART) which takes in a string of characters and converts it to a value. The project was done individually.

Project 3 built on the program from the second project, and used the UART driver to make a full calculator. Students were given a module to interface with, which output values to the UART. The project stressed on modularity and code reuse. This was the first of the two team-based projects.

The final project was run as a competition between the teams. They were assigned 2 sorting algorithms and asked to pick a third wildcard sort. For each algorithm, bonus points were awarded to the team whose implementation had the fewest number of instructions and the team whose implementation executed in the fewest cycles. A presentation that included a code walk-through was required from each team. A rubric was provided for the presentation. Individual reflections were turned in by the students at the end of the four PLP projects. These reflections were driven by prompts, but encouraged students to write free-form. Detailed feedback was given on the reflections in order to guide students to write better and to be more reflective.

Comprehensive Assessment for Team-Member Effectiveness (CATME) (Ohland, Pomeranz, & Feinstein, 2006; Ohland et al., 2012) was used for team creation and peer evaluation in the team projects. CATME team creation works by administering a student surveys about teamwork criteria (e.g. availability, leadership style, material comfort level, etc.). This data is used to match students as closely as possible based on instructor parameters for similarity or diversity of each criterion. Upon completing team projects, students not only rated themselves and their team-members based on their knowledge, skills and contribution to the project, but also provided free-form comments about the team experience.

In-Person Course Format. Keeping with the high weightage for the projects, the in-person class assigned over 50% of the class periods to mentoring of teams by the instructor and TA as they worked on their projects in the classroom. Taught as a partially flipped class, tutorials posted on YouTube, and a detailed user manual with examples supported the in-class teaching and mentoring. Regularly scheduled office hours were also provided by the instructor and TAs. Students were given one week for project 0, two weeks for project 1, three weeks for project 2, four weeks for project 3 and five weeks for the final project. In both project 3 and the final project, students worked in teams of 3. Teams for both projects were the same unless students reported serious issues through CATME evaluations, in which case members were redistributed.

Online Course Format. The online section of the microprocessors course is fully asynchronous, but not self-paced. A 7.5 week schedule is followed for each online course, with weekly instruction modules and weekly deadlines for assignments, quizzes and exams. Because the online course is asynchronous, Piazza (Piazza, 2016) was used as a discussion board in place of in-class mentoring to allow students to pose questions to instructors, TA and other students.

Having questions answered by peers through a formal channel is a unique feature of the online course. The closest equivalent within the in-person course is informal interaction before, during and after class, and in general on campus. Literature on social constructivist theory and the zone of proximal development (Vygotsky, 1978) indicates that student to student communication may be more effective than teacher to student communication (Smith, Peterson, Johnson, & Johnson, 2001). Piazza was used extensively by students over the 7.5 week course with a total of 331 total posts (questions and notes) and 2283 total contributions. The average response time for a new question was 11 minutes. Piazza allows students to post questions with various levels of anonymity. Each question has sections for two answers, an instructor answer and a student answer, which any user of the corresponding type can edit at any time. There is also a follow-up section for related questions that allows for and nested replies to these to these follow-ups. Follow-ups questions have the a pair of radial buttons at the top to mark the question as resolved or unresolved, which makes finding lingering questions easier for instructors.

Online students were asked to complete project 0 during the short first week and were given one week for the project 1. The remaining projects were allocated two weeks each. Office hours were held once a week via Adobe Connect, an online meeting tool, so that students were able to ask questions in real time about projects and other course material. The differences between the online and in-person course are summarized below in Table 1.

Table 1.
List of Differences in the two courses

Variable/Factor	**Online**	**In-person**
Course Length	7.5 weeks	15 weeks
Meetings/Lectures	Asynchronous	Synchronous twice per week
Office Hours	Online (Adobe Connect)	In-person
Project Mentoring	Piazza	In-class mentoring every other meeting
Student-student interaction	Piazza	In class and on campus
Team Sizes	Project 3: pairs Final project: teams of 3	Project 3: teams of 3 Final project: teams of 3

Methods
The research question we ask is, “How well do activities and projects designed for an in-person cooperative project-based learning translate to an online class?” To answer this question, we compare data from the in-person and online versions of a Microprocessors course.

Design. The experimental design consisted of comparing two sections of the same class taught in the same semester by the same instructor with the same teaching assistant. Almost all the quizzes, projects, and exams were identical, and the course outcomes listed on the syllabus were exactly the same for both courses. There were some differences in course length and the make-up of the student body, as presented in the previous section.

Site and Participants. The research was conducted, and the two courses were offered, at a research-intensive PhD granting university in the United States of America. Both courses were offered for credit as part of a BS degree program in Software Engineering. Students enrolled in the in-person Software Engineering program were a mix of residential and commuter students. Some were employed full time; most were employed at least part time. Many online students had either a prior BS degree in another major, or had transferred at least 24 credit hours to the software engineering BS degree. While exact demographic data for the two sections was not recorded, the online software engineering students tend to be older than their in-person counterparts. The Microprocessors is meant for freshmen/sophomore students in the software engineering program. In practice, majority of the students enrolled in this particular assessment sample were juniors/seniors in terms of credits taken. There were 92 students in the in-person class and 105 in the online class.

Assessments and Procedures

Quantitative analysis was performed based on student scores on artifacts for particular course outcomes, and student scores for particular assessments for the two courses. In particular, the courses were set up such that just under 70% of a student's course grade was derived from artifacts that were turned in individually, such as quizzes, the final exam, the first two course projects and all project reflections. Just over 30% of the student's grade was derived from cooperative activities comprising of two course projects. All quizzes were administered online for both classes, and allowed students to refer to notes, browse the Internet, and use any source to help them come up with the correct answer. The final exam for the in-person course was administered in class with a total time limit of two hours, and also allowed students to refer to notes and browse the Internet. The online students were given four days to take the final exam. A two-hour time limit was not set, but only one attempt was allowed, and students were allowed to refer to notes and browse the Internet while they took the test.

Results

Grade Distributions. Table 2 shows three sets of distributions each for the online and in-person courses. The first two rows of the table show the distribution for the overall, the next two rows show the distribution for the individual component of the grade, and the last two rows the distribution of the team component of the grade grades. Each number in a cell is the percentage of students from that section who got that particular grade range, so each row should add up to 100. In order to visualize the distributions, they are plotted in Figures 1 through 3.

Table 2.
Grade Distributions

	A	B	C	D	F
Overall Grade Online	50.00	20.21	8.51	4.26	17.02
Overall Grade In-Person	39.77	23.86	12.50	7.95	15.91
Individual Online	34.04	26.60	12.77	8.51	18.09
Individual In-Person	22.73	22.73	20.45	19.32	14.77
Team Online	40.43	19.15	8.51	7.45	24.47
Team In-Person	52.27	11.36	12.50	4.55	19.32

Figure 1 shows the distribution for the overall course grade, which indicates some differences between the two courses, but the overall trend is similar. Both show a saddle-curve with a right-tailed distribution. However, the percentage of students who got an A in the online section (50%) is greater than the percentage of students who got an A in the in-person section (39.77%).

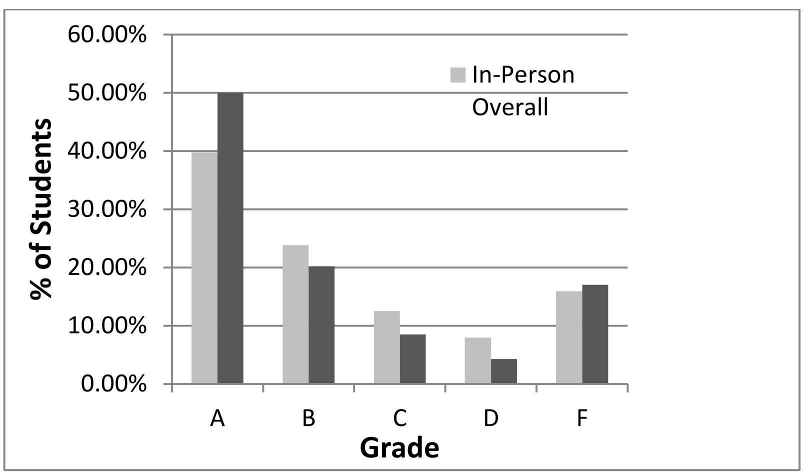

Figure 1. Distribution for the overall grade

Figure 2 shows the distribution of the individual component of the grade for the online and in-person classes. For the online section, there is a clear saddle-curve with a right-tailed distribution. However, a different trend is observed for the in-person class, where the percentage of students in each grade category is almost the same (with the exception of F). This seems to be in contrast to the overall grade distribution for the in-person students. Compared to the online students, one can infer that a smaller percentage of the in-person class is making A's and B's on individual work, and a higher percentage is making C's and D's compared to online students.

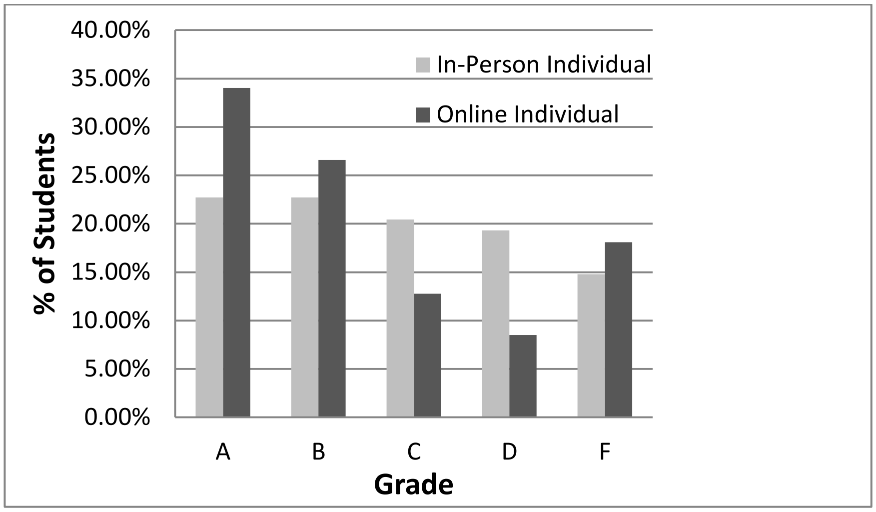

Figure 2. Distribution for the individual grade component.

Figure 3 shows the distribution for the team component of the grade. While the saddle-curve is also observed for both sections, just like Figure 1, there are some clear differences. The percentage of students in the A category is higher for in-person (52.27%) than online (40.43%). This seems to be almost exactly the reverse of the A category in Figure 1. Similarly, the trend for the B category is also reversed, with a much higher percentage of students getting a B for their group work compared to in-person students. Taking into account these differences for A's and B's, and tying them back to Figure 2, an interesting inference can be drawn: For in-person students, grades for group work are helping overall grades, much more than for online students.

Quantitative Analysis

In addition to observing the overall trends above, student's performance data from online and in person classrooms was subjected to a series of series of statistical tests to detect reliable differences between groups. For these analyses, an □ level of .1 significance due to the one tailed (directional) nature of the hypothesis and predictions (Gravetter & Wallnau, 2015). In addition to tests of significant differences, Cohen's *d* measurements of effect size are also reported. These effect sizes are a representation of how strong the general effect is with larger numbers representing stronger effects. As a general rule, a Cohen's d effect size of .2 is considered small, .5 is a medium effect size, and .8 and above is a large effect size (Cohen, 1988). However, effect sizes are sensitive to variability in the data and the more noise in the implementation environment (uncontrollable events) the smaller of the effect size (Shadish, Cook, & Campbell, 2002).

Individual Assignment performance. A t-test was conducted on student's average scores on individual assignments to determine if there were differences between students in in-person and online classrooms. This test did not reveal any significant differences and almost nonexistent effect size ($t(174.26)=.115$, $p = .910$; $d=0.045$). The observed mean for in person students was $M=.74$; $SD=.19$ and for Online students it was $M = .75$, $SD = .25$. Based on the non-significant test, the tiny effect size and the nearly identical means (See Figure 4), student performance on the individual assignments was statistically identical.

Team Assignment Performance. A t-test was conducted on student's average scores on individual assignments to determine if there were differences between students in in-person and online classrooms. This test indicated a significant differences and a small to medium effect size

Figure 5. Comparison of team component of grade for in-person and online sections

($t(174.15)=1.71$, $p = .09$; $d=0.26$). The observed mean for in person students was $M=.83$; $SD=.26$ and for Online students it was $M = .75$, $SD = .34$. Based on the observed data, student performance on the group assignments was significantly lowered in online classes compared to in person student group performance (See Figure 4 for graph of means and standard error bars).

Qualitative Data

Student Reflection Essays. A detailed qualitative analysis of student reflection essays is outside the scope of this paper, but some student reflections are presented below, to capture some of the nuances of the team dynamics. For example, one of the students from the online class whose CATME comment indicated a negative team experience wrote the following in his final reflection:

"My group faced several major problems in coming together to complete the project. The first was schedules. At the beginning of the time frame my partners met to divide work, but I was unable to attend due to my schedule. XYZ complete the implementation of insertion sort early on and I was able to reach him over the weekend to coordinate roles, but our other group member disappeared. Once that was out of the way I took ownership of implementing bubble sort and the wildcard sort and XYZ took ownership of the presentation. Once roles were established XYZ and I worked together with no major issues.

On the project management side I did really learn much, but reaffirmed a few lessons for previous group work.

1. *Most groups function best with a leader or at least a clear division of labor.*
2. *Scheduling, communication, and deadlines are essential.*
3. *Technical proficiency should be utilized to determine roles."*

It seems that despite being unhappy with the effort that one of his teammate put in, the student did collaborate well with the other team member, and was able to have a positive learning experience. He was also able to reflect on what he learned from the experience. Another example from a student from one of the online teams that the instructor and TA deemed to be a low performing team wrote the following:

"Personally, this was the most challenging project for me because of the group aspect. I have done many group projects for school and have never struggled with a teammate as I did with this project. Even though we did the CATME matches, we had 1 member of our group that was able to work on the project at different times than the other two, and they were very difficult to work with because they expected us to have work done at the same time as they did. It also seemed that all 3 of us weren't highly skilled in the class, so it was difficult to try and help one another when we ran into issues. Overall, I was pretty disappointed with my performance on this project, as it was the first one that I was completely unable to get working. However, I have learned a great lesson in working with others on a project like this. Even though I prefer to just write code by myself, in a professional environment, there will be several developers working on the same code."

Discussion

The overall observation from the data, whether it is the teamwork grade component, the impressions of the instructor and the TA, or the comments from the students, is that cooperative learning was not as effective in the online class as it was in the in-person class. However, a closer observation reveals that even though it was not as effective, it did work out for some students, and that some teams functioned well. The quotes from the final reflections of students in the online class reveal that even though many students struggled with online collaboration, they still felt that it could be helpful. Students also believed that the lessons they had learned through their teamwork experiences prepared them for future teamwork experiences. Thus it will be interesting to conduct a longitudinal study in courses that follow the Microprocessors course, in the online program.

The comparison of cooperative learning in the two courses reveals a pattern, but more importantly, it prompts us to ask questions and opens up avenues for further research. Several possible factors or different combinations of these factors could be responsible for what we have observed. The differences between the two implementations can be grouped into three categories: *Student characteristics and attitudes, course mechanics, and the interaction framework for student-student and faculty-student interactions.* The instructor and the TA believe that factors from all three categories contributed to some extent, and that some factors are interrelated. For example, the 7.5 week timeline was considered the most challenging by the instructor and the TA, as that not only gave the online students less time to work on the projects, but affected the interaction between the course facilitators and the students, as the timeline for grading and providing feedback was also pushed up. Other factors in the course mechanics, such as discussion forums for student teams to collaborate with each other, and for course facilitators to interact with students also played a role. We propose to gather data in all three categories for future implementations of online and in-person classes in our program, and conduct in-depth studies to investigate the factors and their contribution to the phenomena observed.

Another important point for discussion is the lack of existing research in this area, in the context of engineering and CS education. A study of prior IEEE Transactions on Education articles, FIE papers, and SIGCSE conference papers revealed four articles that were somewhat related and only one article that was closely related. This most closely related article (LaMeres & Plumb, 2014) compared the online and in-person versions of a digital design class. Unlike their study, both online and in-person students used identical tools to complete the projects discussed in our study. In LaMeres and Plumb (2014), online students remotely controlled lab equipment or used other online tools such as Web simulations in order to account for a lack of direct access to all laboratory equipment. The biggest difference between their study and this paper is that they do not focus on comparing collaborative and individual efforts. All assignments appear to be individual in nature and do not touch on the challenges of managing collaboration in an online-only environment. We believe that much more research in this area is necessary, to enable effective cooperative learning for CS and software engineering online programs, and the research can be informed by work (Allen, Bourhis, Burrell & Mabry, 2002; Merisotis & Phipps, 1999) done outside of CS and engineering education.

As a result of instructor and TA experiences from the semester being analyzed in this paper, it was decided that collaborative projects should be replaced by individual projects in the online course. One complaint shared by many students in less successful teams was that they were unable to communicate with at least one member of their team. This issue is compounded by the fact that there is an expectation that the online course is asynchronous, meaning students choose when they will be active. A second factor that complicates team interaction is that the online course progresses at twice the speed of the in-person course, so the in-person students have twice as many possible meeting times as the online students. The in-person students are also guaranteed one class period per week in which they can meet and have synchronous communication as they see fit, but the same guarantee cannot be made for students in an asynchronous online class.

Conclusions

This paper presents observations from a direct comparison between an online and an in-person implementation of a class with the same instructor, same teaching assistant, same course objectives, and almost identical assessment methods for these course objectives. The results clearly show that cooperative learning techniques do not translate 'as-is' from the in-person implementation to the online one. While this finding might be somewhat expected, it illustrates that faculty who are well-versed with research-based innovative pedagogies for in-person classes, do need to re-train and familiarize themselves for online classes. From the administration's perspective, it is important to note that just assigning their 'star' faculty to teach online classes is not sufficient, and that training and appropriate release time should be provisioned to faculty for developing and delivering online classes.

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Combining Program Assessment with Learning Management for Efficient and Sustainable Accreditation Processes

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Abstract
Academic programs in colleges and universities are often required to conduct periodic program assessment to ensure the quality of the program and to obtain accreditation. A rigorous assessment process is difficult to implement due to the significant effort and resources required. In this paper we present an open-source web-based software system developed at the Computer Science Department at CSULA that tightly integrates program assessment functions with learning management functions. We show that such a system can greatly improve the efficiency to collect, analyze, and present assessment data. Furthermore, building assessment functions into a learning management system, which many faculty and students use on a daily basis, also encourages and facilitates a continuous and sustainable assessment process.

Introduction
Many colleges and universities conduct periodic reviews of their academic programs to ensure the quality of these programs. In some disciplines, the programs are also required to obtain accreditation to show that the education they provide to the students meets the national or global standard for the discipline. Conducting a rigorous program assessment can be a daunting task - students need to be interviewed and their portfolios collected, various constituencies need to be surveyed on both educational objectives and learning outcomes, rubrics need to be developed and evaluated, course journals need to be compiled, focus groups need be organized, and the list can go on and on. All the assessment data must be collected, analyzed, documented, and presented in a way that leads to decisions and actions. And what makes it even more difficult is that instead of doing these once every few year, a truly meaningful and effective assessment process must be *continuous* - as stated in Criterion 4. Continuous Improvement in ABET Criteria for Accrediting Computing Programs [1] (emphasis mine): "The program must *regularly* use appropriate, documented processes for assessing and evaluating the extent to which the student outcomes are being attained. The results of these evaluations must be systematically utilized as input for the *continuous* improvement of the program."

Many software systems, both commercial [2, 3, 4] and homegrown [5, 6, 7], have been developed to facilitate the program assessment process. These systems, which we refer to as *program assessment systems* (PAS), typically allow users to define learning outcomes, create rubrics for the learning outcomes, and use the rubrics to evaluate student work such as portfolios. Some PAS, particularly the commercial ones, also support advanced analytics and visualization of the assessment data. The main problem of PAS is that they are rarely used in the day-to-day teaching and learning activities. The common scenario is that a school would employ a PAS to get accreditation, and then the system will not be used again until a few years later when the school is up for accreditation review again. So despite the usefulness of their assessment functions, PAS, in our opinion, actually promote the bad practice of assessment for the sake of assessment rather than assessment for the continuous improvement of the program.

Unlike PAS, learning management systems (LMS) such as Blackboard [8] and Moodle [9] have become part of the daily educational activities in many schools these days. There are two reasons that make LMS a potentially useful tool for program assessment. First, LMS host a wealth of data such as student work that is valuable to program assessment. Second, the use of LMS in day-to-day teaching and learning makes it a suitable place to embed assessment activities for continuous and sustainable assessment processes. However, typical LMS are not designed with program assessment in mind. In particular, they do not organize, analyze, or present data in meaningful ways for program assessment purposes, and their support for common assessment methods is either lacking or limited.

In this paper we present CSNetwork Services (CSNS), an open-source, web-based software system developed at the Computer Science Department at California State University, Los Angeles (CSULA). CSNS integrates the functions of learning management, program assessment, as well as student administration and advisement into one system; and by doing so, CSNS achieves a level of efficiency that is not possible by loosely coupling several special-purposed systems.

CSNS provides a number of functions and tools for program assessment, including:

- Managing program vision and mission statements.
- Managing and mapping of ABET criteria, educational objectives, student learning outcomes, and courses.
- Course-level assessment tools such as rubrics and course journals.
- General-purposed tools that can also be used for program assessment, e.g. surveys, file manager, wiki, and mailing lists.
- Importing and managing data from external standardized tests such as Major Field Tests (MFT).
- Analyzing and presenting assessment data from various sources.

The rest of the paper is organized as follows. Section 2 gives an overview of CSNS, and Section 3 focuses on the functions and tools for program assessment. In Section 4 we discuss our program assessment process and how CSNS helps to facilitate and streamline this process. We summarize our experience and discuss some ongoing work in Section 5.

CSNS Overview

CSNetwork Services (CSNS) was originally developed as a simple homework submission system for Computer Science classes in 2006. Over the years, more and more functions were added, and it has become a comprehensive system that supports teaching, learning, administration, advisement, and program assessment. By the end of 2015, the system is used by 600-1000 users on a daily basis.

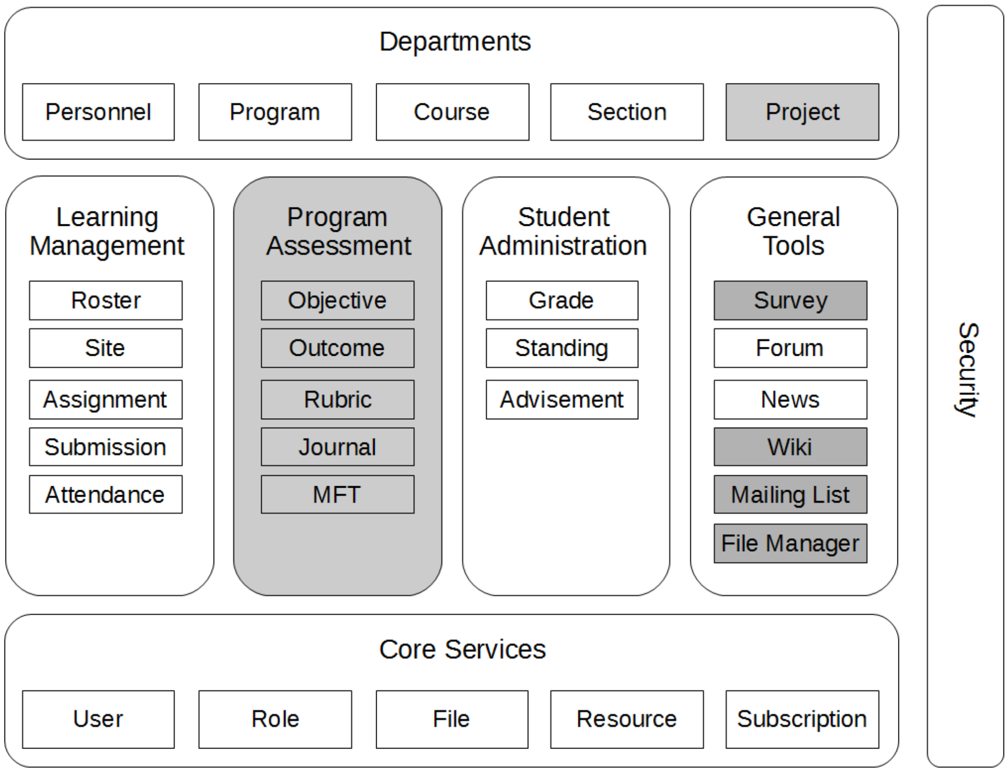
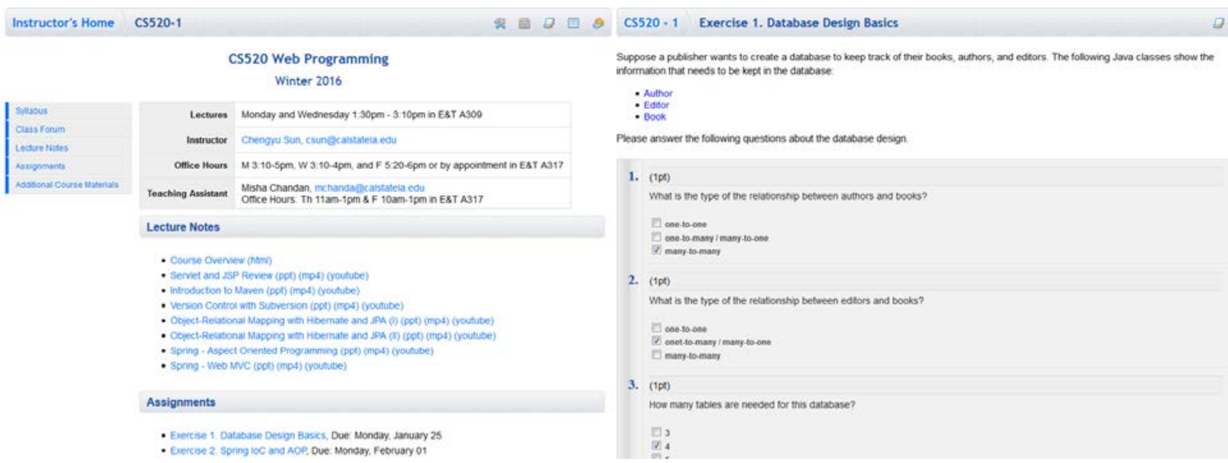


Figure 1: CSNS Overview

Figure 1 shows the architecture of the system with the components used for program assessment highlighted. Although CSNS was originally designed only for the Computer Science Department at CSULA, the current version of CSNS can support any number of departments. Each department can manage their own personnel (department administrators, full-time and part-time faculty), programs, courses, sections, and senior design projects. Each department also has access to a number of functions and tools which can be grouped into four categories: learning management, program assessment, student administration, and general-purposed tools. The core services provide support for users, roles, files, resources, and subscription management. Security is implemented and enforced at all levels.

CSNS provides the basic functions that one would expect from a learning management system. At the beginning of a term, an instructor can create a new class and import the class roster from the university student registration system. A class website can be easily created by either cloning an existing class website or building a new one from a template. As shown in Figure 2(a), a class website consists of one or more *blocks* (e.g. a `Lecture Notes` block and an `Assignments` block), and each block contains one or more *items*, which can be uploaded files, or URL links, or documents created and edited directly on CSNS. Blocks and items can be easily added, edited, removed (or hidden), and rearranged. An instructor can also post assignments on CSNS, and depending on the assignment type, the students can either upload their solutions as files, or complete the assignment directly online as shown in Figure 2(b). The system can enforce assignment requirements such as due date and the types of the uploaded files, and for online assignments that contain only multiple-choice questions, the system can automatically grade the assignments.



(a) (b)

Figure 2: Class Web Site and Online Assignment in CSNS

CSNS also provides a number of online tools, including surveys, forums, news (i.e. announcements that appear on the front page), wiki, mailing lists, and file hosting. Unlike in other LMS where these tools are tied to classes, in CSNS they can be used both inside and outside classes. For example, an instructor can create surveys for his or her class, and a department chair can create surveys for alumni. And in addition to course forums, CSNS also has department forums for subjects such as job opportunities and advisement, and system-wide forums that discuss issues such as the design and implementation of the system.

The student administration functions in CSNS include keeping track of student grades, changes of academic standings, and advisement records. These functions work closely with other components of the system. For example, changing the academic standing of a student from B (Undergraduate Student) to BG (Graduated with BS/BA Degree) will automatically unsubscribe the student from the students and the undergrads mailing lists and subscribe him or her to the alumni and alumni-undergrad mailing lists. As shown in Figure 1, CSNS also provides many program assessment functions, which we will discuss in more details in Section 3. Overall, compared to the very class-centric approach taken by most LMS, CSNS is designed to meet a much broader set of needs of an educational institution.

Program Assessment Functions

In CSNS, each department can have multiple programs, and each program can have its own vision and mission statement, assessment criteria (e.g. ABET a-k), educational objectives, and student learning outcomes. The system can also keep track of the mappings of the criteria, objectives, outcomes, and courses. As shown in Figure 1, many CSNS components are used for program assessment. In particular,

- *Senior Design Project Listing* hosts the artifacts of each senior design project, including documents such as project requirements document and project report, which are part of a student's web portfolio.
- Program assessment documents are hosted on *Wiki* and *File Manager*, which makes it easier to share and collaborate on these documents.
- *MFT* imports the Major Field Tests scores, compares them to the national distribution, and tabulates and charts the results.
- *Mailing Lists* are used to contact the constituents and get their feedback.

Of all the components involved in program assessment, *Course Journal*, *Rubric*, and *Survey* are particularly important. In this section we cover these three components in more details.

Course Journal Functions

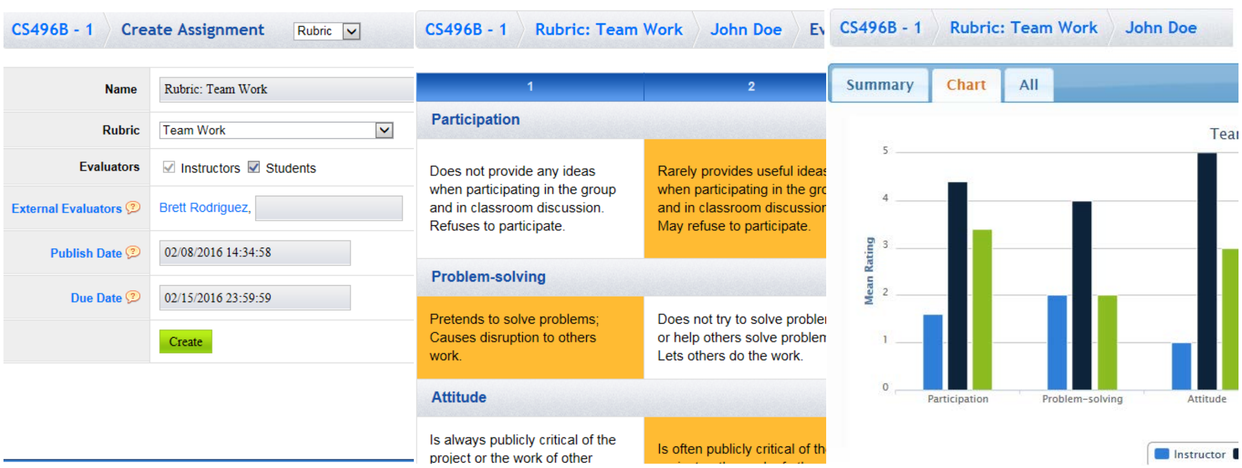
ABET Accreditation (http://www.abet.org/) requires that a course journal be compiled for each course in the curriculum for accreditation review. A course journal consists of a course description, a course syllabus, all the lecture notes, handouts, assignments and exams, and three samples of student work. Compiling a course journal used to be tedious work that consumes lots of time and resources. An instructor needs to print out all the course materials, which can easily reach a few hundred pages. And to collect the student samples, an instructor often needs to ask some students to resubmit their assignments, and print out those as well. With CSNS, compiling course journals becomes much easier since most of the course materials and student work (including grades and the instructor's feedback) are already hosted on CSNS. CSNS also provides functions to compile, present, submit, and approve course journals so the whole process can be conducted online (and many trees can be saved).

In our ABET accreditation review in 2013, the online course journals were approved by the ABET review team, but there was some confusion from some courses where the course journal items lacked descriptive names or assignments that should be excluded (e.g. make-up tests) were included. After the ABET review, we revamped the course journal functions, and now each course journal item can have a descriptive name and can be a hyperlink, or an uploaded file, or HTML content created directly on CSNS. Also instructors now have the option to exclude some assignments from a course journal.

Rubric Functions

In the last few years, ABET has put more and more emphasis on the use of rubrics in program assessment. Collecting and processing rubric data can be a complex and tedious process. Most rubrics are evaluated in multiple classes, and rubric evaluation often involves not only the instructors, but also the students (i.e. peer evaluation) and other stakeholders such as project sponsors and employers. Every year data in the form of thousands of spreadsheets must be collected, processed, and analyzed, which adds significant workload to the already overworked faculty and staff. The Rubrics component of CSNS is designed to simplify rubric management, data collection, aggregation, and analysis.

A *rubric* in CSNS has a number of *performance indicators* evaluated on a numerical rating scale (e.g. 1-5). For each rating for a performance indicator, there is a description about the criteria for the rating. All instructors can create and manage rubrics on CSNS using a web interface. Some rubrics are designated as department rubrics, which can only be edited by department administrators.



(a) (b) (c)

Figure 3: Rubric in CSNS

A rubric can be evaluated in a class as a special "assignment". For example, Figure 3(a) shows a Team Work rubric assignment created in a capstone course. Note that there are three types of rubric evaluations: *instructor*, *peer*, and *external*. Instructor Evaluations are conducted by the instructor(s) of the class. Peer Evaluations are conducted by the students in the class. External Evaluations are conducted by external reviewers such as senior design project sponsors, employers, and Industry Advisory Board members.

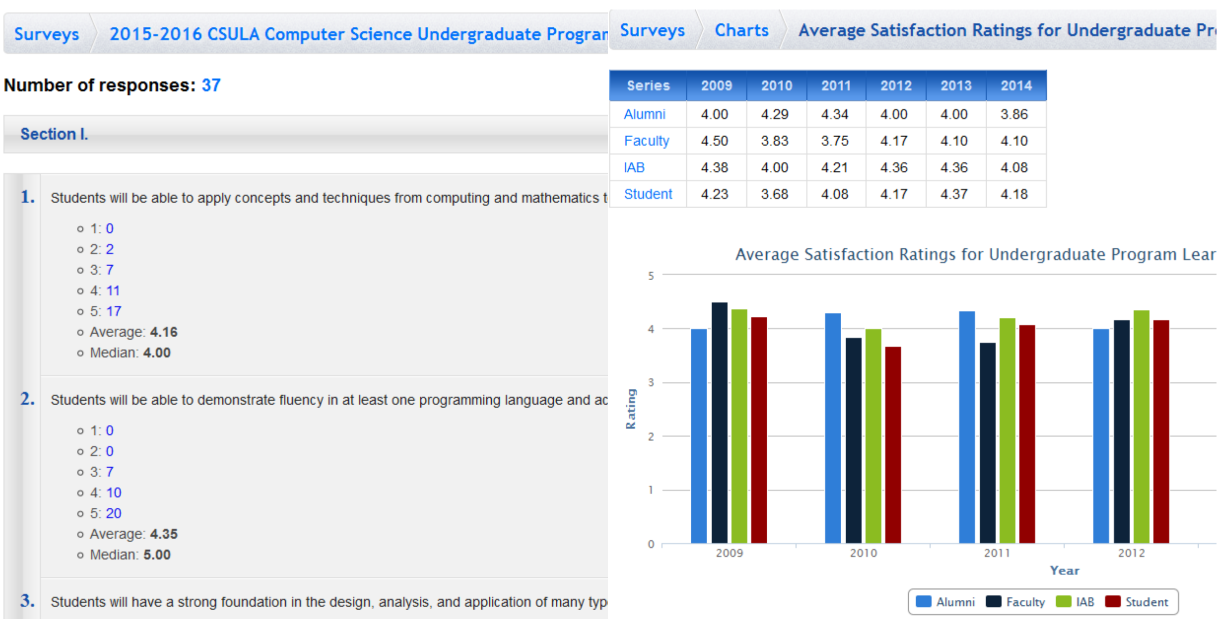
To evaluate a rubric, an evaluator can simply click on the criteria description that corresponds to the rating for a performance indicator, as shown in Figure 3(b). An evaluator can also leave additional comments, which is not captured in the screenshot in Figure 3(b) due to space limitations. Rubric evaluations are automatically aggregated by the system based on the combinations of several factors: rubric, person, class, evaluation type, and year. The aggregated data is tabulated and charted to help visualizing and analyzing the data. For example, the chart in

Figure 3(c) shows the mean rubric evaluation scores for a hypothetical student John Doe by an instructor, an external reviewer, and the other students in the class.

Survey Functions

Surveys are an important direct measure for program assessment. CSNS supports three types of surveys. An *anonymous* survey is open to the public, i.e. no CSNS account is required, and the system does not keep any information about the people who took the survey. A *named* survey requires the users to log onto CSNS to take the survey, and the system records the identity of the user for each survey response. A *recorded* survey also requires the users to log onto CSNS to take the survey, but the system only records whether a user has taken a survey or not, i.e. a survey response is not connected to a particular user to maintain some level of anonymity.

Each survey has one or more *sections*, and each section may contain a number of questions. Currently CSNS supports three types of questions: *rating questions* that ask the respondents to give an integer rating from a specified range, *choice questions* that ask the respondents to select one or more options, and *text questions* that ask the respondents to enter their answers as text. A survey cloning function is provided to quickly create a new survey from an existing one, and this function is very useful for surveys that need to be conducted periodically (e.g. annual student outcome surveys).



(a) (b)

Figure 4: Surveys in CSNS

One way to summarize and visualize the survey responses is to use the *response summary* function, shown in Figure 4(a). A survey response summary shows the total number of responses and some aggregated data for each question, including the number of responses for each choice or rating, the mean and median ratings for rating questions, and the answers for text questions.

CSNS also provides a *survey chart builder* that allows users to build charts based on the results of different surveys. Specifically, a chart consists of one or more *sequences*, and each data point in a sequence is an aggregated value (e.g. mean or median) of a rating question in a survey. For example, suppose we want to create a chart that shows the satisfaction ratings of the first learning outcome from 2009 to 2014. The user can create a sequence named Student. To add a data point to the sequence, the system will let the user first select a survey, then select a question from the survey. So for the Student sequence, the six data points are the first question in each of the six Annual Student Survey on Learning Outcomes from 2009 to 2014. Similarly, the user can add additional sequences based on the surveys to other constituencies such as faculty and alumni. Figure 4(b) shows the resulting chart. Note that new data points can be easily added to the chart after new surveys are conducted.

Program Assessment Process

In this section we introduce the program assessment process at the Computer Science Department of the California State University, Los Angeles (CSULA), and show how CSNS helps to facilitate and streamline this process. It should be noted that no matter how good an assessment system is, it only plays an assisting role in the process, and the success of program assessment and accreditation is ultimately determined by the people, not the computers.

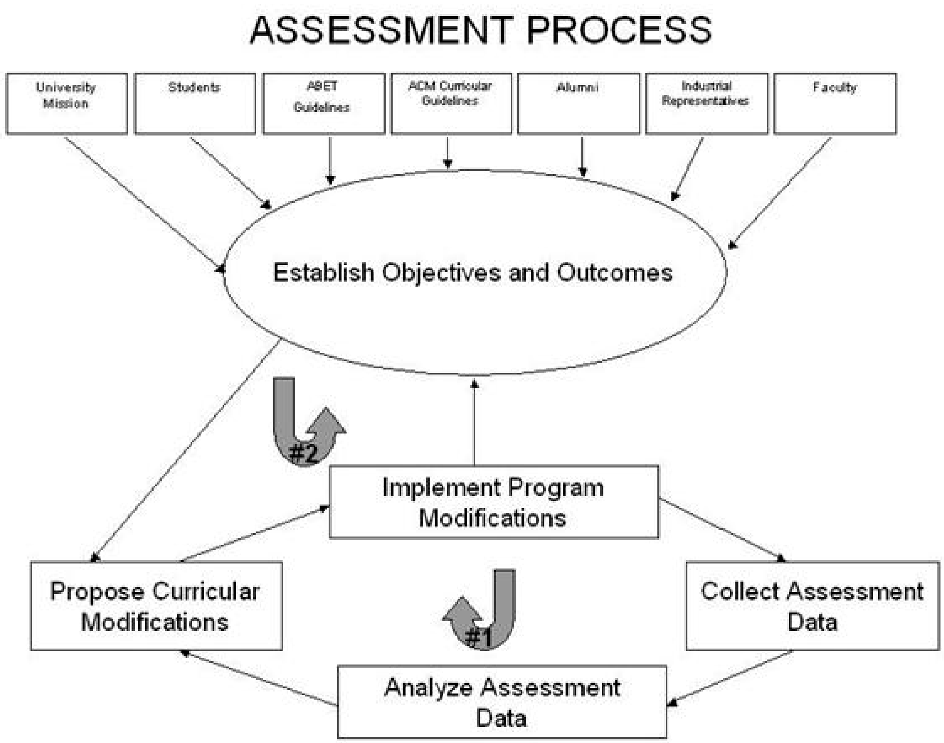


Figure 5: Program Assessment Process at Computer Science Department, CSULA

Figure 5 shows the two-loop program assessment process at the CS department at CSULA. The outer loop, Loop #2, shows the periodic process involved in establishing, assessing, and revising the Program Educational Objectives. This process employs the feedback from various constituencies of the program, and is conducted primarily using CSNS surveys. Loop #2 is a relatively slow loop where assessment occurs once every five years. Currently we are considering shortening the cycle to three years.

The inner loop, Loop #1, describes how the Student Learning Outcomes are evaluated by collecting data from various measures. Loop #1 is a fast loop where the outcomes are assessed annually to ensure continuous improvement both at the course level and at the program level. Results of each year's assessment measures are used to provide information to help guide refinements to the program.

Rubrics

We developed six rubrics:

- Team Work
- Oral Communication
- Written Communication
- Software Engineering – Requirements
- Software Engineering – Design
- Software Engineering – Implementation

These rubrics are evaluated on CSNS in the Software Engineering course sequence CS337 and CS437, and the Senior Design Project course sequence CS496A/B/C. These courses are required courses and are offered at least once every academic year.

Standardized Exams

The Major Field Tests (MFT) is designed by the Educational Testing Service (ETS) to measure the knowledge and understanding obtained by students. The MFT exam is currently utilized by over 230 institutions and more than 9,100 students. This direct measure provides comprehensive data that enables us to evaluate student performance and compare it to programs at similar institutions nationwide. The MFT also provides three indicators:

- Assessment Indicator #1: Programming
- Assessment Indicator #2: Discrete Structures and Algorithms
- Assessment Indicator #3: Systems: Architecture/Operating Systems/Networking/Database

Each indicator provides the average percentage of the correctly answered test questions in that content area for the class as a whole. These indicators are closely tied to our learning outcomes. Students taking the capstone course CS490 Computer Science Recapitulation are required to take

MFT. The scores and the national score distribution data are imported into CSNS, which provides functions to manage, analyze, and visualize the data.

Also conducted in CS490 is an internally designed standardized exam. Modeled after MFT, this exam tests Computer Science knowledge of the students in four areas: Theory, Programming, Algorithms, and Systems. This exam is given as four online assignments that the students complete on CSNS.

Surveys

Surveys are indirect measures that gather perceptions, opinions, and reflections on learning. Surveys also provide a means to ask qualitative open-ended questions. Every year we survey five of our constituencies - students, faculty, alumni, employers, and industry partners, on the importance and satisfaction with our learning outcomes. The feedback on satisfaction indicates how well we achieve each learning outcome, and the feedback on importance lets us know if we should modify the outcomes themselves.

These surveys are conducted annually on CSNS. We use CSNS mailing lists to contact the students, faculty, and alumni, and we ask our alumni to direct their immediate supervisors to our employer surveys. The surveys of industry partners are conducted at the annual Industrial Advisory Board (IAB) meeting. The survey results are aggregated, tabulated, and charted in CSNS, and serve as the basis for our decision making in continuous improvement.

Course Assignments

Since courses contribute to the achievement of student learning outcomes, data can be compiled from courses to evaluate those outcomes. These direct measures are in the form of course assignments such as projects, papers, exams, presentations, and portfolios. The assignments we use for assessment purposes are carefully determined by the program assessment committee, and are standardized regardless of the instructors of the course. In most cases, the artifacts collected from these assignments are a part of a student’s assessment portfolio.

The learning management functions in CSNS allow instructors to easily create assignments. Depending on the type of the assignment, students can either upload their solutions as files, or complete the assignment online using a web browser. Assessment data is collected from selected assignments every time the course is offered, which is usually once or twice a year.

Assessment Documentation

We believe a good program assessment process should be clearly defined and well documented. The vision and mission statements, educational objectives, and student learning outcomes of our program are available online to the public. We also systematically document our assessment process, including the mappings of ABET criteria, objectives, outcomes, and courses, as well as the assessment measures used and data collected for each learning outcome. Furthermore, all the assessment documents, including not only the self-study report and annual assessment reports, but also assessment-related plans, papers, presentations, meeting agendas, and so on, are also available online to various parties involved in the assessment process. All the assessment documentation is hosted on CSNS File Manager and Wiki, which provide easy and controlled access, and facilitate sharing and collaboration on the documents.

Conclusion and Ongoing Work

In this paper we introduce CSNetwork Services (CSNS), an open-source, web-based software system that combines the functions of learning management, student administration, and program assessment. We show that such a system can greatly reduce the time and resources required to collect, analyze, and present assessment data, so the institution can focus more on perfecting the assessment process and improving teaching and learning. Furthermore, building assessment functions into a learning management system, which many faculty and students use on a daily basis, also encourages and facilitates a continuous and sustainable assessment process.

We have been continuing to improve CSNS since it went into operation in 2006. The current work is focused on the organization and presentation of the assessment data in the system. In particular, we are working on a user interface that provides both program assessors and reviewers easy access to all the assessment methods, results and analysis in an intuitive and coherent manner.

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3D Printing of Fiber-Reinforced Polymer Matrix Composite: An Engaging Technique for Undergraduate Education and Research

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Abstract
The high strength-to-weight ratios of fiber-reinforced composite materials have enabled their widespread use as structural materials in weight-critical applications such as aircrafts, aerospace structures, high performance racing vehicles (sport cars, bicycles), sports equipment (skis, snowboards), and prosthetics. To date, the manufacturing of fiber-reinforced composites is still a predominantly manual and labor-intensive process—rather than an automated process—owing to several reasons: (i) highly customized and complex geometries, (ii) high cost of tooling for typically low-volume production, and (iii) autoclave curing upon layup of fibers or prepregs, all favor manual manufacturing over automation. Nevertheless, the goal of infusing more automation into the making of composites is still an ongoing quest within the composites community. In this paper, we experimented with direct 3D printing of polymer onto aligned and random fibers to explore the fabrication of fiber-reinforced polymer matrix composites (PMC) using fused deposition modeling (FDM) 3D printing technique. The goals of the project are several folds: (i) to investigate the feasibility of direct 3D printing of polymers onto aligned fibers to make PMC without post-processing steps such as autoclaving, (ii) to identify the optimal pairing of polymer and fibers, (iii) to facilitate learning of the mechanics of composite materials for freshman and sophomore community college students through hands on experimentation. To this end, a team of four community college mechanical engineering sophomores, working under a NASA Curriculum Improvement Partnership Award for Integration of Research into Curriculum (CiPAIR) grant, were tasked with researching the feasibility of using a commercial 3D printer (Ultimaker 2) to directly 3D print thermoplastic polymers including polylactic acid (PLA), acrylonitrile butadiene styrene (ABS), carbon XT-CF20, NinjaflexTM polymer, and SemiflexTM polymer, onto commercially available fibers. The chosen fibers are unidirectional carbon fiber, S2-glass woven cloth, E-glass woven cloth, E-glass modified twill woven cloth, and E glass random fiber mat. To find an optimal combination for fiber-matrix composites, the student researchers used a multitude of fibers and filaments to test which combination yields the best ultimate tensile strength, elastic modulus, ductility, resilience, and toughness. We have successfully demonstrated that it is feasible to 3D print thermoplastic polymer directly onto fibers to create composites. Our preliminary results further show that, interfacial bonding between fibers and as-printed thermoplastic polymer is a key factor affecting the integrity and mechanical properties of 3D printer composites. Our test composite specimens show improvements in their ultimate tensile strength-to-mass ratios and toughness as compared to thermoplastic without fibers.

Introduction

Additive manufacturing (AM), generally known as 3D printing, is a burgeoning manufacturing field that has witnessed rapid expansion in recent years due to its capability in producing complex functional components at low cost and in a fully automated manner. To date, a myriad of 3D printing techniques have been developed, including fused deposition modeling (FDM), stereolithopgraphy (SLA), digital light processing (DLP), selective laser sintering (SLS), selective laser melting (SLM), electronic beam melting (EBM), and laminated object manufacturing (LOM). Among these techniques, FDM has been most critical in driving the commercialization, affordability, and popularity of 3D printing for the consumer market due to its process simplicity, system robustness, and less stringent requirement on materials choice. The corresponding increase in market demand for 3D printing has in turn refined the capabilities of affordable desktop FDM printers as well as led to broader application for the printed products. Currently, commercial 3D printed parts made using FDM technology are typically made of thermoplastic polymers such as polylactic acid (PLA), acrylonitrile butadiene styrene (ABS), or polyamide (nylon). While these polymers are readily available with well-known properties and can be melted at low temperatures (<200°C), they generally lack the temperature resistance and strength required for use in structural or other load-bearing applications. Therefore, there exists a critical need for materials that can be printed yet possess more superior mechanical properties that enable their use as structural components. Incorporating high-strength, high-stiffness reinforcement materials in a thermoplastic matrix to create a composite structure could potentially enhance the mechanical properties of a thermoplastic.

Conventional polymer matrix composite (PMC) materials such as carbon fiber-, glass fiber-, and aramid-fiber reinforced polymers (CFRP, GFRP, or AFRP) have long been known for their high strength-to-weight capacities and excellent structural efficiencies. For these PMC composites, continuous or discontinuous fibers or woven clothes made of high strength or high modulus graphite, E-glass, S-glass, or aramid (Kevlar^{TM} or Nomex^{TM}) are embedded in thermoset polymer matrices such as epoxy, polyester, bismaleimide, cyanate ester, phenolics, or polyimide. For larger scale production, resin-preimpregnated woven clothes or *prepregs* are preferred, where the clothes have been previously infused and saturated with uncured polymers, which are ready to be assembled into the desired structures. Thermoplastic polymers-based PMCs are less common and used mainly in high-performance military aircrafts applications. They are less accessible to the consumer market due to the high pressure required to process the highly viscous and oftentimes thixotropic polymer melts, making them very costly to produce. Despite the market being dominated by thermoset-based composites, once formed and unlike thermoplastic, thermoset cannot be remelted and reformed into other shapes, making it impossible to repair a thermoset composite in the event of minor damage. In addition, assembly of thermoset-based composites are largely done via manual and labor-intensive wet layup process, resulting in substantial materials waste, high cost, and relatively low production. Hence, there exists room for developing a low-cost thermoplastic-based carbon- or glass fiber-inforced composite systems that is catered to the consumer market, with relatively good mechanical properties, easy to process and repair.

The goals of this work are several folds, chief among the goals are: (i) to explore the fabrication of low-cost thermoplastic based fiber-reinforced composites via FDM printing technology, (ii) to engage and retain minority sophomore community college students in engineering via an introductory, exploratory and hands on 10-week summer research project at the forefront of engineering and which the students can intellectually *own*. To these ends, four community college students were teamed up with a graduate student mentor and a faculty mentor from a four-year college to investigate the feasibility of using FDM to fabricate fiber-reinforced composite materials. The objectives of the student team are to: (i) investigate the feasibility of direct 3D printing of thermoplastic polymers onto aligned fibers to make PMC without post-processing steps such as autoclaving, (ii) identify the optimal pairing of thermoplastic polymer and fibers and develop a fabrication technique that could produce uniform and homogeneous fiber-reinforced composite specimens, and (iii) test and compare the mechanical properties of these fiber-reinforced composites against printed thermoplastic control specimens for validation of material property enhancement.

Materials and Experimental Setup

Materials. The thermoplastic materials used in the FDM printing process are polylactic acid (Ultimaker), acrylonitrile styrene butadiene (Ultimaker), a short carbon fiber-infused copolymer of polyester and polylactic acid named ColorFabb XT-CF20 (MatterHackers), and NinjaFlex SemiFlex polymer (MatterHackers). Unidirectional graphite fibers (6K tow, 4.4 oz/yard^2), E-glass modified twill woven cloth (8.9 oz/yard^2), S2-glass woven cloth (3.64 oz/yard^2), and E-glass mat (0.75 oz/ft^2) are all purchased from TAP Plastics Inc.

Compatibility of a matrix and fiber combination is crucial for obtaining a true composite with beneficial material properties when compared to its constituents. Based on this requirement we investigated a total of 16 matrix-fiber combinations to identify optimal combinations of fiber and matrix. Depicted in Figure 1 are the four types of fibers used, which include: (a) S2-glass woven cloth, (b) E-glass modified twill woven cloth, (c) E-glass fiber mat, and (d) unidirectional carbon fibers. Figure 2 shows the four types of matrices used, which included PLA, ABS, XT-CF20, and SemiFlex polymer. Each fiber will be paired with all four of the matrices, resulting in a total of 16 different composite materials.

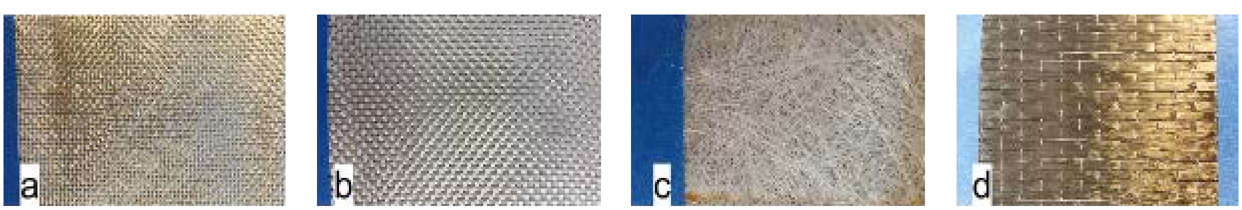

Figure 13: Photos of specimens before the incorporation of matrix materials. (a) S2-glass woven cloth (b) Modified twill E-glass woven cloth, (c) E-glass random mat, and (d) unidirectional carbon.

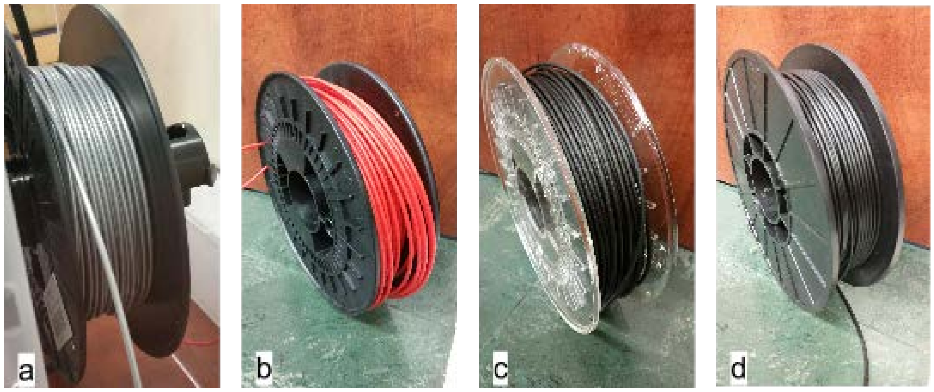

Figure 14: FDM matrices in the form of filament rolls: (a) PLA filament, (b) ABS filament, (c) XT-CF20 carbon-incorporated polyester-polylactic acid copolymer, (d) NinjaFlex SemiFlex filament. The colors of the filaments have no bearing on their general properties.

Fabrication and Characterization. An FDM printer, Ultimaker 2 (Ultimaker), was used in the printing of PLA and ABS polymers. During printing of these polymers, the print head temperature was set to above 190°C to ensure full melting and to allow for sufficient time for polymer to adhere onto the fiber surface. To test the mechanical properties of the as-fabricated composites, the specimens were cut into flat tensile test specimen dimensions using a 60W carbon dioxide laser cutter (Full Spectrum Lasers) in accordance to ASTM D 638-02A (Standard Test Methods for Tensile Properties of Plastics). Tensile test was performed on an Instron tensile machine (Model# 3369, Instron Inc.). Images of the specimens were recorded using a Nikon digital single lens reflex (DSLR) camera (Nikon D5100) fitted with a 20mm extension tube (XiT).

Results and Discussion

Direct Printing of Composite Laminate. Direct printing of the four polymers was performed on each of the four fiber types. Figure 3 shows the printing-in-progress of a PLA on an E-glass modified twill woven cloth and unidirectional carbon, respectively. To ensure proper deposition of polymer melt onto the fibers, we began by reconfiguring the set programs commonly used in a commercial FDM printer, Ultimaker 2. A 2’’ x 2’’ sheet (print area) was first designed in Solidworks software with a minimal thickness of 0.015”, which was then translated into a standard manufacturing instructional code—G-code—through Ultimaker’s Cura Engine slicer and input into an Ultimaker 2 FDM printer. 4” x 4” fiber sheets were next secured to the build plate of the Ultimaker 2 with blue painter’s tape. The machine was then calibrated to the height of the fiber sheet and the print was conducted. This process was iterated for the 16 fiber-matrix combinations. During the printing process, the temperature of the polymer melt deposited on the fiber could reach up to 190°C. At this temperature, the viscous polymer melt was capable of penetrating and wetting the matrix. In addition, it was discovered that by disabling the printers cooling fans and increasing the build platform’s temperature, the matrix could stay in a semimolten phase for a longer duration, which enhanced the wet-out (polymer impregnation) of the fiber and improved the adhesion of the matrix on the fiber.

It is worth mentioning that, to enable uniform printing of polymer matrix onto fibers, a systematic method was developed. The customized and standardized procedure resulted in the printing on both sides of the fiber in order to encapsulate the fiber in a printed matrix. Each fiber type required its own print model to account for the variation in layer height, producing a uniform final thickness of 0.115”. Once printing was completed on the top surface of the fiber, the specimen was removed and flipped over, pressed between a flat surface and the heated print bed for 10 minutes to prevent curling of samples edges during the cooling process. The machine was then recalibrated to account for the added height of the new layer of polymer. The next polymer layer was then printed over the fiber to complete the “sandwich” structure.

Overall, once the machine was properly calibrated, we were able to print polymer directly onto the fibers. We consider this a successful initial demonstration of the feasibility of direct 3D printing of composite materials. In other words, this technique could potentially offer a feasible, automated and low-cost route to making thermoplastic composite material, once all the process parameters are optimized. These process parameters would include: polymer melt temperature, platform temperature, controlled cooling rate, proper fiber surface treatment to enhance adhesion, and humidity.

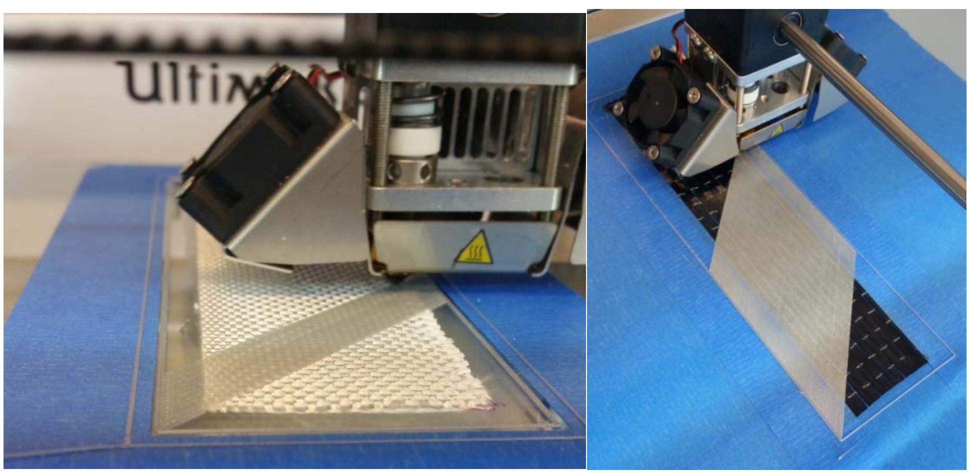

Figure 3: FDM printing of PLA on (left) E-glass modified twill woven cloth, and (right) unidirectional carbon.

Printed Matrix-Fiber Interaction and Fiber Selection. Figure 4 shows the as-printed specimens. We performed qualitative analyses on the test specimens based on their textures, adhesion quality, layer thickness, edge formation, and overall integrity of the as-printed shapes. Based on the results from test samples seen in Figure 4 it was determined that PLA and SemiFlex possessed the desirable qualities as optimal matrices. PLA has a minimal thermal mismatch enabling for relatively deep penetration of the polymer through the fiber cloths, allowing for proper bonding between PLA and the selected fiber cloths. Thermal incompatibility issues were observed between the matrices XT-CF20 and ABS and the fibers, as manifested in the curling and warping of matrix edges. Figure 5 shows an as-printed ABS polymer matrix that, in the process of cooling down to room temperature, detached cleanly from the fiber surface, starting from the corners—an indication of poor adhesion. As film detachment could occur while the printing was in progress, inconsistencies in the height of the printed matrices could result, leading to rough surface finish. PLA and SemiFlex displayed the strongest adhesion to the fibers. This is clearly shown when the printed matrices were forcefully pried away from the fiber, they pulled the fibers along instead of peeling back from the fibers. Moreover, despite the flexible nature of SemiFlex, which caused printed SemiFlex to easily warp and bend at the corners, no detachment of matrix from the fiber was observed. From these findings it was determined that PLA and SemiFlex were suitable candidate materials to be used as matrices for direct printing onto fibers to make composites.

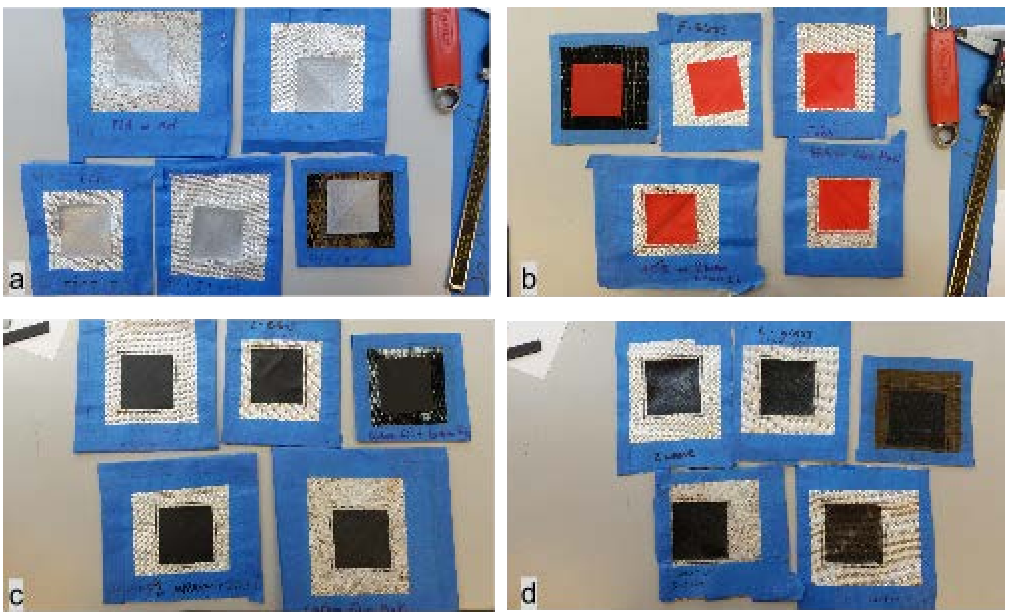

Figure 4: As-printed composite samples with the following matrix materials: (a) PLA, (b) ABS, (c) XT-CF20, and (d) SemiFlex on E-glass modified twill cloth, S2-glass cloth, E-glass mat, and unidirectional carbon fiber. Only the top sides of the fibers are printed with polymer, with the purpose of testing the fiber-matrix adhesion.

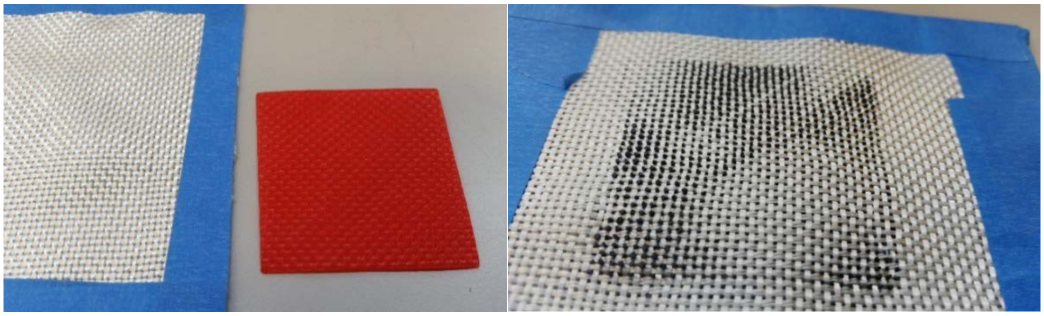

Figure 5: (Left) As-printed ABS (red film) that was cleanly detached from an E-glass modified twill woven cloth. The detachment began at the corners of the matrix-fiber interface as the matrix cooled down from its melting temperature. (Right) When flipped over, SemiFlex directly printed on one side of E-glass shows good wet-out characteristic, and therefore good adhesion.

Laser Post-Processing of Tensile Specimens. Once printing have completed, the as-printed material were cut into the desired tensile test specimens with a 60W CO_2 laser cutter. Laser cutting is a fast and precise machining technique that is suitable for cutting polymers into predefined shapes reliably with good repeatability. There are three main factors to consider in the laser processing of a specific material: the absorption of the material, its thermal diffusivity, and its reaction temperature. These factors involve knowing how much energy the material absorbs from the cutter, the speed at which the heat absorbed by the material is conducted away (thermal conductivity), and its melting point and vaporization point. The key challenge in laser cutting the materials of interest is that, due to the different degree of heat absorption and heat dissipation by the different materials, the actual volume heated up by the laser is different for each material. This heated volume is generally known as a *heat-affected zone* (HAZ). Figure 6a illustrates the large region of reflowed material (SemiFlex) that formed beads and lips in the HAZ, whereas Figure 6b shows the edges of a PLA/carbon that is relatively unaffected by the HAZ. In Figure 6a, a notch that was to be laser cut in the center of the gage length of the specimen became blunt and unrecognizable due to melting at the edges of the specimen caused by heating from the laser. Due to severe change in dimensions and geometry that is caused by laser cutting, SemiFlex was not used for tensile testing.

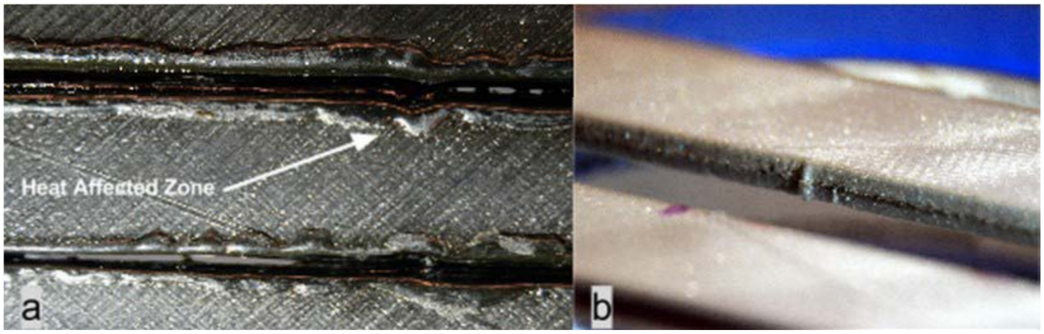

Figure 6: (a) The heat affected zones of a SemiFlex-carbon composite is substantial compared to that in a (b) PLA, which is hardly visible.

Tensile Testing and Failure Analyses. We performed tensile tests on PLA and PLA composite specimens using an Instron 3369 tensile tester and specimens that followed the ASTM D638-02A standard (Figure 7a). Through the adhesion tests, we found that PLA exhibited the best adhesion with the fibers, compared to the other matrix materials, including SemiFlex. Therefore, for tensile testing, we focused on investigating PLA as a direct-print matrix material, so as to allow for meaningful comparison of the properties of PLA composite specimens made with E-glass, S2-glass, and carbon fiber with two types of purely PLA specimens: a single-step solid print (single print) and a two-step solid print (double print). The differences between a single print PLA and a double print PLA lies in how the specimens were fabricated. In a single print PLA, the specimen was printed in a single run from start to finish with no additional process before the print was completed. For a double print PLA, the specimen was initially printed to half its intended thickness, flipped over, with the other half printed on top to complete the specimen. The purpose of a double print PLA is to mimic the manner in which the PLA-composite is made, which follows the same steps as the double print PLA, with the fiber sandwiched between two PLA layers. Doing so would allow for a more accurate comparison between PLA and PLA-fiber composites. In order to control the location of failure the samples were laser-cut with a round notch in the center of the specimen's gage length, as shown in Figure 7b. This notch acted as a stress concentrator and allowed the specimen to fracture next to the notch and completely within the gauge length.

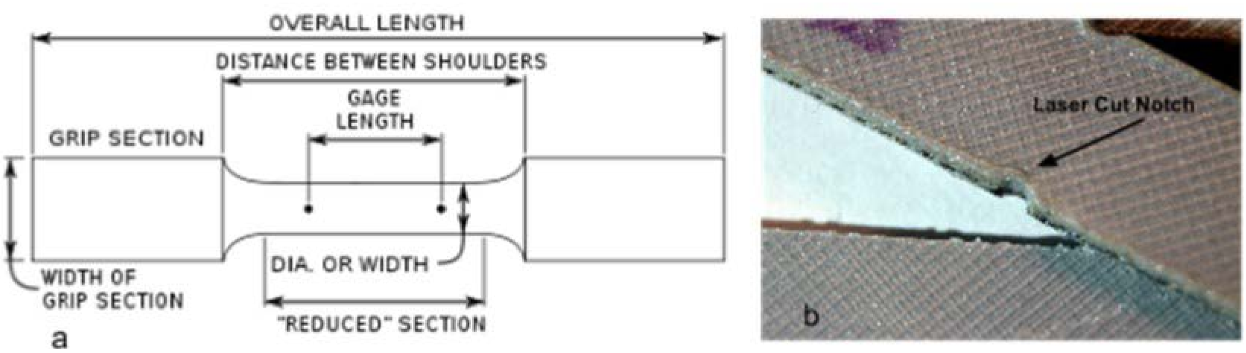

Figure 7: (a) Schematic of a standard tensile test specimen. (b) A laser-machined round notch to enable fracture to occur completely within the gage length section of the specimen.

The tensile tests were informative as they provided a preliminary understanding of the mechanical properties (Young's modulus, ultimate tensile strength, and toughness), interfacial bonding, and failure properties of the PLA-fiber composites. Table 1 shows the average values of the ultimate tensile strength-to-mass ratios, Young's modulus, and toughness for each of the five types of specimen. Single print PLA is used as the control specimen, whereas double print PLA is considered the baseline since its fabrication steps closely mimicked that of direct-print PLA/E-glass, PLA/S-glass, and PLA/carbon composites. Compared to double print PLA, the ultimate tensile strength-to-mass ratio of all three composites were between 10%-17% higher, showing promising improvement in this important yardstick for the PLA-fiber composites. In terms of Young's modulus, PLA/carbon composite exhibited the highest average modulus value at 3.26 GPa, significantly higher than 2.28 GPa for a double print PLA and 2.88GPa for a single print PLA. This translated to an impressive 43% and 13% improvements, respectively, over the double print PLA and single print PLA. Finally, all PLA-fiber composites showed higher toughness, measured as area under the stress-strain curves of each of these specimens, than both the double print PLA and single print PLA. This indicates a tougher material that can absorb more energy before fracture.

Figure 8 shows the post-fracture tensile specimens. In the PLA specimens, both single print PLA and double print PLA specimens fractured in a clean manner. For the PLA-fiber composites, the composites did not completely fracture. Instead, when fracture were observed in the outer PLA layer, the tensile tests were halted. Upon close examination of the PLA/E-glass composite and the PLA/S-glass composites, some of the longitudinal fibers were observed to have been stretched and fractured, whereas the transverse fibers were seen to have bonded well with the PLA matrix with minimal fracturing. Finally, the PLA/carbon composite did not bond as well as the two PLA/glass composites.

Table 1: Experimental values of Ultimate Tensile Stress-to-Mass ratios, Young's modulus, of PLA (single print), PLA (double print), PLA/S-glass, PLA/E-glass, and PLA/carbon. All values are the average experimental values of three identical specimens.

Materials	UTS/Mass [MPa/g]	E [GPa]	Toughness [J/m³]
PLA (single print)	4.22	2.88	0.73
PLA (double print)	3.79	2.28	1.10
PLA/E-glass	4.35	2.31	1.18
PLA/S-glass	4.44	2.07	1.53
PLA/Carbon	4.16	3.26	1.16

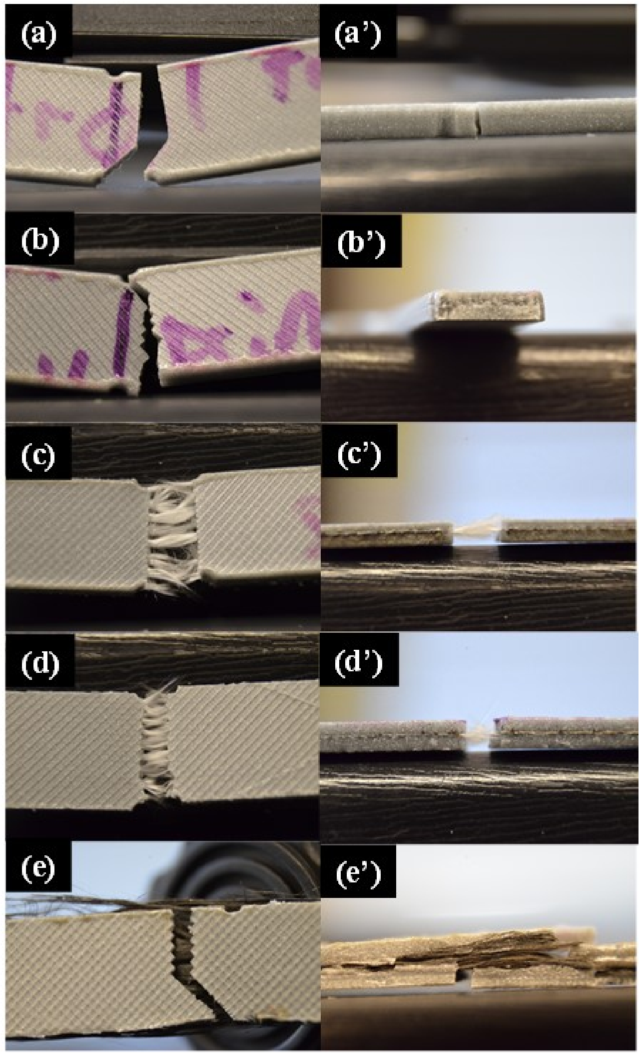

Figure 8: (a-e) Top views and (a'-e') side views of tensile specimens after fractures. The specimens are: (a, a') PLA (single print), (b, b') PLA (double print), (c, c') PLA/E-glass composite, (d, d') PLA/S2-glass composite, and (e, e') PLA/carbon composite.

Influence on Student Learning. A very important goal of this research project is to engage freshmen and sophomore community college minority students in active learning through hypothesis generation and hands on experimentation. Ultimately, through a research program such as this, the hope is to increase the number of minority and female students choosing Science Technology Engineering and Mathematics (STEM) field as a career, and to improve their retention and graduation rates. While the long-term impact of this project will not be known until 2-3 years later, exit surveys of this group of 4 students, together with 12 other similar students involved in a computer engineering, electrical engineering, and civil engineering projects, respectively indicated the overall experience as being positive. Table 2 shows the overwhelmingly favorable responses the students gave when asked to rate their learning from the project. Clearly, this project and the corresponding program have exerted a tremendous influence on young Engineering students to continue in their fields.

Table 2. Responses to the question of "As a result of your participation in the program, how much did you learn about each of the following? "

Activity	**Score**
Performing research	4.81
Designing/performing an experiment	4.75
Creating a work plan	4.63
Working as a part of a team	4.63
Writing a technical report	4.75
Creating a poster presentation	4.69
Making an oral presentation	4.81

Response Scale: 1 – Nothing; 2 – A little; 3 – Some; 4 – Quite a bit; 5 – A lot.

Conclusion

We have successfully demonstrated that it is feasible to 3D print thermoplastic polymer such as PLA, ABS, and SemiFlex directly onto E-glass modified twill woven cloth, S2-glass woven cloth, unidirectional carbon fibers to create composites that have relatively good bonding strength. Our preliminary results indicates that compared to as-printed thermoplastic, the incorporation of fibers enhanced the ultimate tensile strength-to-mass ratio and toughness of the thermoplastic composite. We further showed that, interfacial bonding between fibers and as-printed thermoplastic polymer is a key factor affecting the integrity and mechanical properties of 3D printer composites. With a better understanding of fiber surface treatment to promote improvement on the interfacial bonding, direct 3D printing of fiber reinforced-thermoplastic composites is technologically feasible method to create functional and complex-shaped composite materials. Finally, additive manufacturing technology, specifically, 3D printing of fiber-reinforced thermoplastic, has shown to be an effective tool in cultivating strong interests in engineering and enhancing deep learning in key engineering concepts at the freshmen and sophomore levels. In the long run, we believe additive manufacturing technologies, owing to its small learning curve and ability to make complex shapes from 3D computer models, could prove to be a powerful tool to attract, engage and retain undergraduate students in the STEM fields.

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Engineers Without Borders Nicaragua Public Elementary School Project: A Case Study in Enhancing Engineering Education through Project-Based Learning

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Abstract
Project-based learning is an essential component of engineering education to prepare students for professional practice. This paper presents a case study through the lens of a public elementary school project in Nicaragua, led by the Engineers Without Borders (EWB) Student Chapter at California Polytechnic State University, San Luis Obispo (Cal Poly). EWB is a student-led organization that partners with developing communities around the world to implement sustainable engineering projects. Projects facilitated by EWB have the potential to enhance engineering curriculum through project-based learning. These enhancements cover both technical and non-technical areas of engineering with a balanced focus on knowledge, skills, and global awareness. The significance of this approach is the involvement of students throughout the entire lifecycle of the project, including project development, design, construction, and assessment of results. The team completed construction of the school project in 2015 after two years of collaboration with the partner community in William Galeano, Nicaragua. The traveling team included 16 students and 2 mentors with multi-disciplinary experiences in development work, design, and construction. In-country construction provided a significant learning opportunity for the students on the trip, as they collaborated directly with the local community members to complete the project on a rigorous construction schedule with limited locally available skilled labor and materials. To maximize the benefits of these opportunities for a broader group of 40 students on the team at Cal Poly who could not travel, the team facilitated a construction workshop on the university campus to practice and showcase field skills. One key challenge for each team member was performing as a responsible global citizen to deliver the project under environmental, societal, and economic constraints. Replicating these constraints in conventional classroom projects is challenging, if not practically impossible. Thus, the project created rare learning opportunities for students on the team. These opportunities covered multiple student learning outcomes in the areas of technical design, problem solving, teamwork, management, leadership, and ethics. Thus, the outcomes of the project reached much farther than the original scope, which aimed to increase access to education for Nicaraguan schoolchildren. Students involved at Cal Poly enriched their education by gaining a more comprehensive understanding of developing and delivering a context-sensitive project in a multi-disciplinary team.

Introduction
As the workplace continues to diversify and industries globalize, it can be challenging for a traditional university education to adequately prepare students for professional practice. This has prompted the *ASCE Body of Knowledge* (BOK) to consider professional experience as an

essential component in engineering education and training (ASCE, 2008). *Table 1* lists the BOK outcomes with respect to experience. As shown in this table, teamwork and collaborative problem solving are skills sought after by employers, which students must cultivate during their collegiate years. Teamwork enhances student success in both research and practice activities as they make progress toward their engineering degree (McComb and Tehrani, 2014). A group approach to experiential learning also prepares students to make the transition into the next phase of engineering education and training as engineers-in-training (Tehrani, 2011). Involvement in extracurricular organizations such as the American Society of Civil Engineers (ASCE) and Engineers Without Borders (EWB) exposes students to unique challenges that allow them to grow in a project-based learning environment (Tehrani, Regier, & Hoffman, 2014).

Table 10 *The BOK outcomes with respect to experience (ASCE, 2008)*

Technical	**Professional**
Design	Communication
Sustainability	Public policy
Contemporary issues	Business and public administration
Risk and uncertainty	Globalization
Project management	Leadership
Technical specialization	Teamwork
	Attitudes
	Lifelong learning
	Professional and ethical responsibility

EWB is an organization that partners developing communities worldwide with student and professional chapters in the United States to collaborate on community-driven engineering development-work projects. A recent study of 505 EWB-USA members across the country evaluated what students had gained from their involvement with the organization. Global perspective was cited as the primary gain these students received through EWB-USA membership (Litchfield & Jayemick-Will, 2013). Despite its relevance to professional engineering practice, an undergraduate education does not typically expose students to the complexities of cross-cultural work. Through EWB, students develop global competency through hands-on experience with international projects. An EWB member must consider cultural boundaries, appropriate technologies, and community input through all phases of project selection, design and implementation. These qualities are well noted as performance measures of a sustainable infrastructure (ISI, 2012).

Community Collaboration through Leadership

From 2013 to 2015, the EWB student chapter at California Polytechnic State University, San Luis Obispo (Cal Poly), completed a public elementary school project with its partner community in Nicaragua (*Figure 1*). The team oversaw all phases of project assessment, design, and implementation. Through this project, students learned practical technical skills as well as soft skills that will support them in their professional careers. In this project, community input drastically influenced the design. For instance, the structure was originally designed with two classrooms and an office, but after further discussing this with the community, the building was expanded to include three classrooms and an office. This change was made after the team learned that in Nicaragua, there are often morning and afternoon sections of classes. By building three classrooms, three grades can be taught in the morning and three in the afternoon, which allows for all six grades of primary education to be offered at the school. The school would not have been successful in meeting the community's needs if community input had not been valued during the design phase of the project. This example indicates how community collaboration is crucial for a project's success. Without community collaboration, an international development project is not capable of meeting a community's needs.

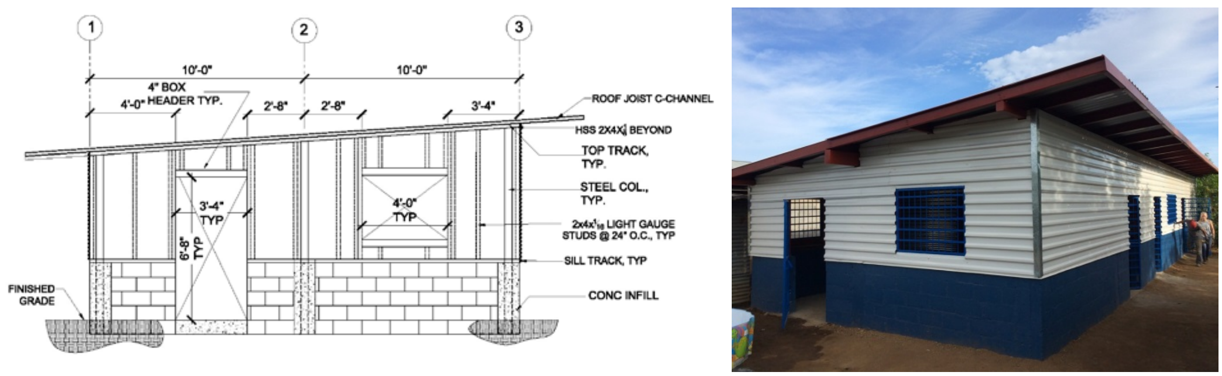

Figure 15 *The design (left) and construction (right) views of the public elementary school project*

By working directly with a partner community and building relationships with local residents throughout the course of the project, students gain an insight into their daily lives and problem-solving strategies. This will often challenge students' existing beliefs about a culture and challenge them to broaden their global perspectives. When faced with a problem in the field, community members are often much more capable of addressing it using local practices than a student would be by implementing a non-native problem-solving strategy. This exchange of knowledge is valuable and humbling for students working on the project. It should be noted that the Nicaragua school project was completed entirely through unpaid voluntary labor from the student team and local community. Thus, by working together, both groups learned from each other and were empowered as stakeholders in the project. For example, on the first school construction trip, a team member was attempting to cut wooden stakes for the foundation formwork using a power saw. The saw was not operating well because the local power source was not strong enough and the wood had a high moisture content. A community member suggested cutting the stakes with a machete instead, which was more effective. On the second construction trip, the corrugated metal roofing material had to be screwed to the roof beams. The design called for the screws to be screwed in the valleys of the corrugated metal to form a direct connection with the roof beams. However, it is local practice to screw into the peaks in order to minimize leaking. The team explained to local volunteers on the construction site why the direct connection made for a stronger structure, which is a practice they can utilize in other buildings in the community in the future. These experiences demonstrate the value of diverse teams and encourage students to become more globally aware citizens and engineers.

Professional Mentoring

Throughout the course of the public elementary school project, students enhanced their engineering education significantly by collaborating with professional mentors. The mentor team for the project consisted of a diverse group of professionals from varied backgrounds. Not only did these perspectives provide valuable insight on technical aspects of the project, but they provided insight into the cultural issues that the team faced as well. Mentors were involved for the entire duration of the project and were consulted from initial project assessment through implementation. This long-lasting relationship with professional mentors gave students the opportunity to form real relationships and expand their professional network.

The design team of four students collaborated with professional mentors on a weekly basis to receive feedback on their designs and ask questions that arose throughout the week. By meeting with technical mentors regularly, students gained a better understanding of the work of practicing structural engineers, as well as experience in professional communication. The design was student-led, so the students often gave assignments for the mentors to complete, rather than the more-experienced engineer giving work to the less-experienced engineer, which would be expected in a workplace. Students also learned to collaborate with and accept critique from others, which is an important aspect of successful teamwork. In the professional engineering world, teamwork is viewed as an important skill, rather than a display of weakness (Jirsa, 2000).

Once the design was approved by EWB, the team traveled to construct it over the course of two, three-week construction trips in the summer of 2015. A professional mentor with experience in structural engineering accompanied the team on each of these trips. On these construction trips, the team collaborated with the community to construct the structure, while effectively dealing with challenges in the field. Students on the travel team also collaborated with the mentors on the trip to make field adjustments to the project based on the availability of local materials. An example of a field modification to the original plan was the formwork design. Boards were not available with the dimensions that the team has anticipated, which complicated formwork construction. Ultimately, the original shape was constructed with two boards constituting one side of the form. Additionally, the team did not encounter finished lumber that could be purchased economically, so the formwork was constructed with rough lumber instead. These implementation challenges provided an excellent opportunity for students to collaborate with mentors and make decisions in the field on a real project.

Communications

The students and these technical mentors prepared for a technical presentation to EWB's Technical Advisory Committee (TAC) for final approval upon the completion of the design. This presentation provided students the opportunity to practice group collaboration and presentation skills. The project's approval was based in part on this presentation, meaning that the students' presentation abilities were crucial for the project's success, as would be true in a work environment.

Context-Sensitive Design

In addition to a presentation on the design, students also prepared an alternatives analysis for submittal to EWB. There were three design alternatives, and the chosen alternative was based on both technical considerations and local constraints in the partner community in Nicaragua. This decision highlights the process of coming to an appropriate solution to a problem based on technical and non-technical design considerations. The team ultimately chose the design alternative with a masonry skirt and a lateral force resisting system consisting of tube-steel columns embedded in concrete pilasters (*Figure 2*). Above the masonry skirt, the design includes corrugated metal siding because of typical construction practices in the area. Masonry was chosen because community members are familiar with masonry and multiple members of the community are masons by trade. Choosing an appropriate alternative was extremely important for the success of the project because many development projects fail due to an improper understanding of the community's needs and capabilities, not improper design or construction (Waugh & Knight, 2013). Understanding the need for local design considerations can help to expand a student's global awareness.

Figure 16 *The structural system (left) and cladding (right)*

While completing the design, the students met with an engineer from the Nicaraguan Ministry of Education (MINED). During this meeting, the MINED engineer gave the team information about local materials and provided the team with the design that is typically used for MINED schools around the country. That design was not determined to be suitable for implementation because it did not meet the strict seismic standards that the team was designing the public elementary school for. However, the MINED engineer approved the team's design even though it was different than the standard elementary school design in the country. By collaborating with an engineer from Nicaragua, the team gained valuable insight and gained experience collaborating with a foreign engineer. This is a valuable experience for engineering students, as they gain a better appreciation for other cultures and how others may define problems differently in different parts of the world (Maldonado, Castillo, Carbajal, & Prabhat, 2014).

Risk Management and Planning

Students prepared for the construction trips by constructing a prototype of one corner of the public elementary school on the Cal Poly campus (*Figure 3*). In addition to training the travel team on construction techniques, the prototyping session allowed for members of the team who weren't traveling to learn more about construction and the project. The workshop invitation was also extended to other engineering students at Cal Poly who weren't part of the EWB Cal Poly Nicaragua team. By allowing a broad range of Cal Poly students to participate, students embodied Cal Poly's "*learn-by-doing*" philosophy. These sorts of activities are known to increase students' excitement about their field of study and help retention rates in engineering programs (Maldonado, Castillo, Carbajal, & Prabhat, 2014). A total of 46 students from nine different majors attended the prototyping sessions, which provided an excellent forum for interdisciplinary collaboration. Two students on the EWB team who didn't already have leadership roles on the team were chosen to be the leaders of the planning and implementation of the prototyping sessions, which allowed the team to cultivate more leaders before the construction trips. For the design team, it was exciting to see the prototype come to life over the course of two weekends. For the rest of the students, it was a worthwhile opportunity to learn about construction techniques and gain a deeper understanding of the design. It was valuable to practice the construction before traveling to Nicaragua to implement the project in actuality, and doing so gave the students the first taste of collaborating with professional engineers to solve technical problems on the job site.

Figure 17 *The prototype constructed on the Cal Poly campus (left) and the workshop team (right)*

One challenge was the difference between the design on paper and what could actually be constructed. For example, one problem on the first trip was the jut-outs in the footing that were complicated to dig accurately in the dry soil. Another problem was the varied concrete pedestal heights, which would have made it impossible to reuse formwork for all of the 19 pedestals that needed to be constructed on the trip. Before the first construction trip, the team reviewed these plans with the mentor team, who gave advice to simplify the design before the trip for the sake of constructability. This simplified design enabled faster and simpler construction, which was critical for the project's success (*Figure 4*).

Figure 18 *Foundation construction before (left) and after (right) placing concrete*

Team Development

Three of the four students on the design team were also on the travel team. The construction trip provided a rare opportunity for the students on the design team to see their work come to life. By traveling, some students who completed the design were also able to work on the job site and contribute labor to the project. Capstone projects can contribute design education, leadership and collaboration skills, but it was a truly unique experience for undergraduate civil engineering students to be able to build something they had designed themselves in the real world. By working on the job site themselves, the students gained a better appreciation for the labor that goes into a construction project, and the real-world constraints that must be incorporated into a constructable design.

By working on a technical project abroad, students gain practical experiences making decisions in an unfamiliar environment and thinking on their feet. During the second school construction trip, the team painted all of the exposed metal on the structure with anti-corrosive paint. This was very challenging, as the paint would begin to dry almost immediately upon contact with the hot metal and become sticky, which made it hard to paint a smooth, even coat. This resulted in an unattractive finish and sections of exposed metal that would be susceptible to rust. To combat this, the team determined that the metal must be painted at cooler times of the day. The daily schedule was adjusted so that the team could get to the site at 6 a.m. to work, take a long lunch break, and then continue working later in the evening after the sun had gone down. The community members were supportive of this solution and respected the team's dedication to the project, oftentimes being the first ones on the work site in the early hours of the morning. By working together to solve a problem in a foreign environment, members of the student travel team enhanced their teamwork skills. These types of experiences all contribute to the development of a competent global leader who is well-prepared to enter the professional world.

Organizing labor in the field was also a challenge for the student-leaders of the project, as all of the labor on the project was completed by the Cal Poly travel team and the community. A significant amount of the labor from the community was unskilled. An important aspect of development work is that the community members are invested in the project and can contribute significantly to the construction, and the team took this consideration to heart when on the job site. Mothers of children who would later be attending the public elementary school came to work on the site in any way they could, whether that be tying rebar for the footing or laying CMU blocks for the walls. It took time to train these members of the community to contribute effectively to the project, but the investment of time was worthwhile. Cal Poly travel team members were also instructed to give their tools to a community member if there were not enough tools for everyone because it was important that the community members gained ownership of the project by working on it themselves. One leadership challenge on the project was balancing the need to complete the project on time with the need to train unskilled members of the community to do work that could be completed faster by someone else. However, the challenges of this project forged strong student-leaders that are now capable of responding to a broad range of challenges in an international engineering environment.

The close relationship EWB members form with student members, professionals, and a partner community aids in developing less-technical skills which are crucial to success in engineering. These skills are helping to answer the call of the National Academy of Engineering (NAE) in *The Engineer of 2020*. In this work, NAE outlined nine attributes, which it predicts will be critical to the success of an engineer in 2020. A study conducted by ASCE members entitled *Investigating Gains from EWB-USA Involvement* stated that "respondents in this study reported explicit gains in at least seven of these nine attributes from their involvement with EWB-USA: technical skills, problem solving, creativity, interpersonal skills, project management (which includes leadership), and humanitarian emphasis" (Litchfield & Jayemick-Will, 2013). In the case of the Nicaragua school project, students also had the opportunity to improve foreign-language skills by communicating with the community directly in Spanish without utilizing a translator. Despite the increasingly global nature of the engineering profession, only 3% of engineering students in the United States study abroad in college (Maldonado, Castillo, Carbajal, & Prabhat, 2014). Organizations such as EWB provide students with the opportunity to travel and gain experience adapting to and working in a foreign environment through a program that is more affordable, accessible, and shorter-term than taking an entire semester to study abroad.

Project Management

As the team project managers, the authors also gained valuable leadership experience. One challenge of project management was adapting to unique challenges abroad and problem solving in a foreign environment. Construction materials were readily available, since the project was in the outskirts of the capital city of Managua, but most construction materials were bought at local markets where negotiation and doing business in Spanish was necessary. Because of this, the student leaders of the project learned to negotiate effectively, because overspending when buying large quantities of materials would push the project over budget. The student leaders also had to plan ahead, as there was larger lead time to acquire some items than there would be in the United States. Hardware stores were not open late at night, and advanced planning was often required to ensure that the team would be prepared for the next day's work. Trips to hardware stores usually took at least two hours, so work would be severely delayed for everyone on the site if even a small, essential tool was missing. If work were delayed on the site for multiple hours, community volunteers would sometimes leave. This meant that sometimes there was not even sufficient labor to complete the job if work continued after a long delay. These challenges shaped the student leaders' own beliefs of what successful engineering work looks like, and made strong leaders that are capable of leading a future international engineering project.

Conclusions

EWB exposes students to the potential for pursuing engineering as a service profession. Students practiced sustainable development by partnering with the community for over five years, ensuring that the projects the team completed could be sustained by the community in the team's absence. If engineering is to serve developing communities, it also needs to consider unique local conditions. To this end, the team completed the design using locally available materials and purchased materials for construction at local hardware stores recommended by community members. Now that the school is complete, elementary-aged students in the community do not have to walk through miles of dangerous streets to get to school in the morning because their community now has a safe and less-crowded alternative.

The EWB Nicaragua school project provided Cal Poly students with extremely valuable learning experiences that extended far beyond technical skills. Students on the team enhanced teamwork, leadership, management, language, and people skills by working to design and build the project over the course of a year. By leading the design, students collaborated with professional mentors, while improving their professional network at the same time. Additionally, students prototyped the design on campus so that all members of the team could learn valuable construction techniques. Through all of this, students truly learned how engineering can be used as a powerful service to communities all around the world, and how their engineering skills can be used to effect change.

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Powerful Small Group Project Presentations to Improve Engagement in Online Computer Science Courses

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Abstract
Being successful in today's engineering world requires working with others in small groups. Small group project presentations are often required in on site classes, to help students develop this skill. However, it can be difficult to provide a comparable experience for online students. This paper discusses an approach enabling student small groups to successfully create and "present" persuasive, effective, engaging PowerPoint presentations in online computer science classes. Small Group presentations have been used successfully in some online classes, by mandating that every member of the class participate in a special synchronous online session where their presentation is made. But, the requirement to participate "live" can be an obstacle. This paper discusses an approach used during the last year which made it possible for online students to participate in a small group project, even if they could not participate in any synchronous class sessions. A significant part of the value of a small group project comes from individuals putting their minds together to work on an issue. In today's distributed world, small group members are sometimes geographically distributed and cannot meet together physically. Large time zone differences can make even make it difficult for them to meet in a conference call. However, there are tools which allow putting their minds together effectively. The Blackboard Learning Management System for online courses has a number of powerful tools enabling small groups to do things like easily exchange files and emails, engage in asynchronous group discussion, and even meet together online "live" if they can find a time that works. Some groups have an initial synchronous online meeting, and then conduct the remainder of their work just exchanging emails and files. Typically, the small groups first discuss the problem, synchronously or asynchronously, and agree on how they will approach it. Each member of the group then prepares one or more voice annotated charts discussing their area of responsibility, and posts it for the whole group for comment. Each member of the group must contribute at least one chart. The process of exchanging voice annotated charts with one another has the effect of causing students to rehearse and refine their part of their presentation. This leads to self-reflection as well as improved quality in the final product. One member of the group finally assembles all the voice annotated charts into a single file, converts it to a streaming video (mp4) presentation using PowerPoint and submits it. The instructor posts it for all members of the class. This is coupled with a Discussion Board question in the LMS in which each member of the class is required to listen to a small group presentation other than their own group, discuss whether or not they agree with the findings of the other small group, and why. Students have found this approach to be an effective learning experience. Some student comments will be presented along with extracts of actual presentations, to show the power of this approach.

Introduction

This paper discusses a methodology that has been successfully implemented to foster community and improve engagement in both graduate and undergraduate online computer science courses. Student course engagement “typically refers to the amount, type, and intensity of investment students make in their educational experiences” (Jennings &Angelo, 2006)

Sarder (2014) comments that making efforts to establish a sense of community within an online course is an effective way to engage students. He goes on to explain that “Community, in the online sense, can be defined as an environment which is enabled through the interaction and collaboration of its members using various technology and mixed media methods,” and “interaction is the essential building block of any community. If members of a community are not able to interact in some form or fashion then it does not exist.” Young and Bruce (2011) note that “Classroom community and student engagement are closely related to one another. Students who feel a sense of connectedness and psychological closeness rather than isolation are better prepared to become more actively involved with online learning and the resulting higher order thinking and knowledge building.” They go on to explain that, “Collaborative learning experiences online can increase participation and connectedness by means of enhanced critical thinking, shared reflections, and helpful feedback among peers within the relatively safe context of anonymity.” They comment that a successful online learning community encompasses two underlying dimensions: social, whereby students feel a personal involvement with others, and learning, which relates to academic content. And they cite small group activities as one of seven ways in which online community can be enhanced. Dixson (2010) found that online instruction required strong methodology and opportunities for students to interact with each other and the instructor, and she noted that one of the recurrent themes in the literature is the effectiveness of using collaborative activities, group discussions, and other forms of student-student interaction. She notes that group projects are one of the types of active learning in online courses that students report as engaging. She goes on to urge that “instructors should consider assignments in which students interact with each other and the content of the course. Instructors need to create not just opportunities for students to interact, but the requirement that they do so. Students who are working on group projects together, doing peer review of one another’s papers, interacting within a discussion forum on a particular topic, are likely to feel more engaged in the course.”

The particular small group projects to be discussed in this paper involve hands-on activities. Harrington and Floyd (2012) state that, “Hands-on activities may be described as “active learning,” which is the opposite of “passive learning,” in which one-way communication from teachers to students is the norm. Active learning involves substantive changes in the ways students and teachers work together, shifting the focus of classroom instruction to student activities such as gathering, analyzing, and presenting data; defining issues; and drawing and defending conclusions. The aim is to create independent and engaged learners.” They also note that “Hands-on learning activities increase student engagement and heighten perceived course value,” and “Student engagement is evident when students demonstrate prolonged attention to a mentally challenging task, resulting in authentic learning and increased levels of higher-order thinking." Zappala (2012) suggests that, "Students who actively participate in the learning process learn more than those who do not.", and he observed that, "Other ways to help assess students' thinking included…Having each student present course concepts to a small group of three or four other students."

The Challenge

Much of the work done in engineering organizations is done in small groups. The businesses that hire our graduates expect graduates will have the skills to work together in small groups. Our Program Learning Outcomes, also require that students will develop the ability to work together effectively in teams. As a result, a requirement to work on one or a few projects in teams of 3 or 4 persons has been a component of a number of onsite courses in our degree programs for many years. The same requirement has typically been transferred to online courses by assigning students to small groups but requiring that every member of the group participate simultaneously in a synchronous online session where the result of their small group efforts is presented.

A significant part of the value of a small group project comes from individuals putting their minds together to work on an issue. Members of groups work together to develop their presentations In online courses this has sometimes been accomplished through exchange of emails, but real time interactions are also needed among small group members to provide the level of interaction that is needed to create community and foster engagement. This is particularly true at the start of a project, when the members of the group set goals and divide up the work. Our online courses always include one or two synchronous online sessions per week which we call "chat sessions." These are for all members of the class who can participate and are normally scheduled in the evening to accommodate the majority of our students who are working adults. It is understood that family and/or work can prevent some individuals from attending one or more chats. All sessions are recorded, and can be reviewed by those individuals at whatever times work for them. To make it possible for small groups to meet, the "chat session" is simply set up as one long session that is available for all members of the class throughout the duration of the course, with every member of the class having moderator privileges. This means that small groups can agree to meet "live" any time they choose, without asking the instructor to set up a special "chat room" time for them. It can happen that two small groups decide to meet at the same time, but they can sort that out among the members of the two groups. It is usually possible for three or four persons in a group to find a time when they can meet simultaneously, although large time zone differences can occasionally make it difficult for some to join.

Small Group Online Presentation Process

Until the last year, all members of a small group in an online course were required to participate simultaneously in a "live" presentation during a scheduled chat session. However, this was sometimes an obstacle, for example for a student whose job required working in the evening. To solve this problem, the format for small group presentations was changed to be a recording put together by the small group. This made it possible for online students to be part of their small group's presentation, even if they could not participate in any synchronous class sessions. This change produced some unexpected dividends, and resulted in small group presentations that could be even better than "live" presentations during scheduled chat sessions. The recorded presentations have generally turned out to be more polished, as a result of the process followed by the small groups. The process used to "produce" a recorded small group presentation helps explain how this can happen.

In the Course Outline, students are instructed to develop a series of voice annotated MS PowerPoint™ charts, as follows:

> "Each member of each group is expected to record their voice presentation for AT LEAST two charts, using the PowerPoint "Insert Audio" command and pulling down to the "Record Audio" option on the menu. After the voice is recorded on each chart, each group's final presentation should be converted to mp4 using the "Export" command under "File" in MS PowerPoint. Be sure to select "Internet quality" instead of the highest quality, to reduce the size of the mp4 file. Both the Voice Annotated PowerPoint file and the mp4 file must be submitted under the Project link on Blackboard before the class in which the presentation will be played for the whole class."

The mechanics of preparing the presentation are simple and easy to understand. The instructor does a simple "walk through" during an early chat session, showing how to insert voice annotation on a chart as shown in Figure 1. The requirement that each member of the group prepare at least two charts is easily enforced, because most student's voices are distinct and easily recognizable. The instructor also explains the powerful group tools in Blackboard which allow small group members to put their minds together including: File Exchange, email automatically addressed to all members of the group, Group Blog, Group Discussion Board, Group Journal, Group Tasks and Group Wiki. The group is free to use/not use any of these tools as they see fit.

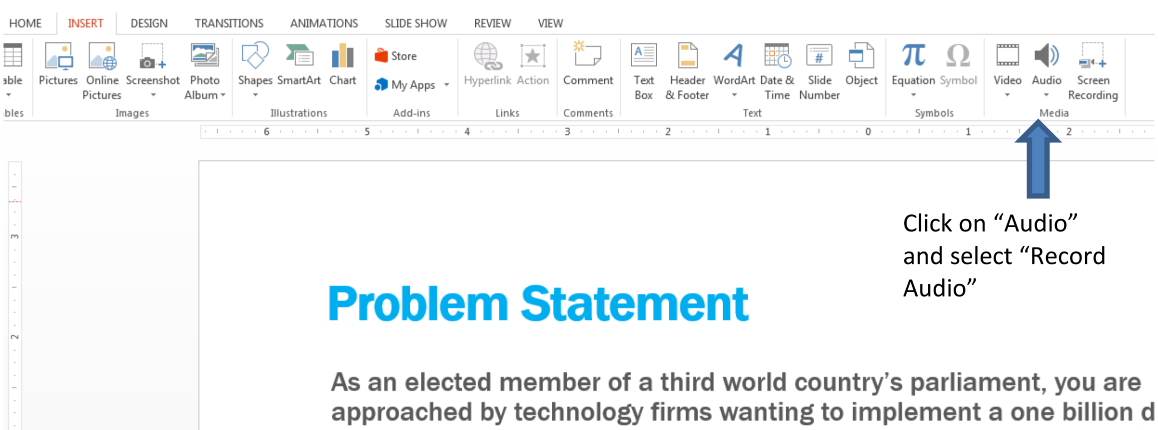

Figure 1 – Use of the MS PowerPoint Inset Audio Command

After small group members meet to divide up the effort, they work individually to carry out any required research, and then develop their charts to discuss their results. Students post their charts in the file exchange for their group to review and discuss each other's findings. Groups are encouraged to appoint a leader who combines the voice annotated charts submitted by each member of the group into a single group presentation. The instructor can view the File Exchange for each small group; it is common to see multiple drafts of the presentation, as the small group discusses and refines the emerging presentation.

The File Exchange capability is critical for the process, because voice annotated charts require much more memory than a PowerPoint chart with no voice annotation. Many email systems will not allow students to email these large draft presentations, which are often more than 20 MB in size. Because it is relatively easy, group members do actually review each other's charts and make comments to each other, resulting in a better presentation. This is consistent with the findings of Dixson discussed above (Dixson, 2010), regarding small group projects in online classes. The process of converting the set of voice annotated charts to an mp4 presentation is straightforward. The resulting mp4 file is submitted to the instructor. The instructor plays the file for the whole class to allow live discussion during a chat session, but this is not the end of the process. The instructor also posts the mp4 file to Blackboard so that any student can listen again, or for the first time if they were unable to attend the chat session where the presentation was played. This also overcomes the inertia which may face some students who don't have time to search through an entire one and a half to two hour chat session recording to find a particular presentation.

Interaction between Small Group and Class Members

To encourage all students to listen to the small group project presentation recordings, whether or not they are able to attend the chat session where it is played, a threaded discussion question requires students to listen to one of the recorded presentations from another group and write at least three sentences discussing whether they agree or disagree with that group's recommendations. This requirement, which was added to online courses only recently, will be refined to require more specific comments, however, it has proved to be useful in promoting group interaction with the class, particularly for controversial topics.

The following is an example of one student's threaded discussion comments on a small group's recommendations in a class on Computer Ethics. The project was taken from their textbook by Reynolds (2012). The small group paraphrased the issue the group was wrestling with:

> "As an elected member of a third world country's parliament, you are approached by technology firms wanting to implement a one billion dollar IT infrastructure in your country. They are willing to pay half of the billion dollar cost. The main benefit of the deal is the one million computers that would be placed in schools, helping future generations gain important competitive skills. Unfortunately, your country is extremely poor, with substandard nutrition, healthcare, power grid,

roads, and phone lines. How do you weigh the benefit of the offer with the other needs of your country?"

The group analyzed the problem by identifying alternatives, and evaluating the alternatives from the perspective of several different ethical theories. Finally, they presented their recommendation. Their analysis invoked Maslow's Hierarchy of Needs (McLeod, 2014), which came out of their research and had not been discussed in the class material. Their recommendation was to tell the technology firms making the offer that the country could not afford to spend $500 million for computers while the basic needs of the people were going unmet. They went on to say that the country needed to build farms and hospitals, roads and a power grid, so today's children can build an IT infrastructure when they grow up. Finally, the group suggested that the firms be invited to invest in meeting the basic needs of the people in the country, with the expectation that when the time comes to modernize the country's IT infrastructure, the country's people would remember those who helped meet their most basic needs.

In his threaded discussion comment, one student disagreed with the recommendation. He commented, "Excellent job on the presentation! While reviewing the presentation I appreciate the introduction to the Maslow Hierarchy of human needs. It shows the importance of what is going on with the people of that country. However, I am not entirely sure it is appropriate to apply it as a needs for the government. I think the opportunity for education to be vastly improved is of equal importance to infrastructural needs of the country. Giving the children a chance to lessen the digital divide could potentially jump start the nation into joining the 21st century instead of simply trying to survive." He went on to suggest that perhaps a compromise could be reached, enabling the country to improve some areas of infrastructure, while still providing a substantial number of computers for schools.

Assessment of Small Group Presentations

Assessment of small group work can be challenging, but it is another critical part of the learning process. Sull (2012) comments, "Be certain all assignment feedback is detailed and positive in tone. Students are obviously in class to learn, and the more material they receive relating to the class subject, the better. To help this along and to keep students engaged, offer on all assignments detailed feedback that leaves the students with a positive feeling, no matter how poorly they may have done." The need for feedback to be positive is an important motivator for the learner. Often this can be accomplished with a simple written "thank you" during the grading process. To ensure that the feedback is detailed, a comprehensive rubric has been developed; it is provided to every student at the start of the course. This rubric is shown in Appendix A.

Appendix B shows the actual assignment feedback provided to the small group that did the analysis of the case study project discussed above. Each row in the assessment matrix refers to one of the rows of the rubric. Each column refers to one of the columns of the rubric. The "X" says that the instructor has assigned this range of values for this particular presentation. The "Comments" provide the instructor's explanation for the placement of the Xs. In classes with multiple projects, the assessment often increases with each project as students' small group skills improve. Students have expressed appreciation for the detailed rubric, and the detailed assessment has rarely been challenged. One advantage of having the final production mp4 recording of the presentation is that the instructor can review the presentation multiple times in developing the detailed assessment feedback.

Feedback from Students Regarding the Process

Students were invited in the final chat to comment on the process of developing their own recordings of their small group project presentations. Responses were enthusiastic. Student's felt they learned a lot from the projects, and that they helped engage them in the learning experience. Most comments were verbal, but one student in a class on Computer Ethics took the time to write at some length about the experience: "…I learned a lot by doing [the recorded presentations]. Our group evolved as we did each presentation. For each of the first two presentations, we had a different person making slides as the three of us met as a group. The presentations used the following pattern: an introduction of the problem, some options before us and which ethical systems they used, and finally the ethical choice we would choose. Our third presentation was transitional, as the problem was more complex, but not all of the group was on board with breaking from convention. Only through hard work were we able to overcome this; in fact, one of my teammates and I had to overrule a third member, whom we felt wasn't contributing enough to the process. For our last presentation … I started out doing research on my own. I found real difficulty wrapping my head around the problem; it was much more complex than even the third topic we presented. When I met with my teammates, I proposed a new strategy which my teammates liked: we all research the problem for a day on our own, and then came back to determine our course of action. When we met again, we all had a different aspect of the problem covered, including some ideas I would never have come up with. We arranged our topics in the order that felt the most appropriate, and each person then was responsible for their own topic, making slides and recording their presentations. Because everyone had contributed equally and found unique interesting points-of-view on the topic, our final presentation was also our strongest."

Use of Small Group Projects to Assess Student Ability to Function in Teams

The process described in this paper has strengthened the ability to measure an important student outcome dealing with the ability to work together in teams. One student outcome for the Bachelor of Science in Computer Science program is the ability to "function effectively on teams to accomplish a common goal" Uhlig (2015). This student outcome also supports a university Institutional Learning Outcome which states that graduates will be able to, "use collaboration and group processes to achieve a common goal as well as a Program Educational Outcome which states that within a few years of graduation graduates are expected to be "effective communicators and team members." The student outcome has been measured in the past through the performance of student teams on their capstone project plus surveys of graduates of the program. Those measures continue to be valuable, but this process provides an additional measure of the ability of students to work together on teams to accomplish a common goal. The specific new assessment measure states that “small groups of 3-5 students investigate a series of ethical dilemmas that are face by computer professionals and give presentations of their findings. The acceptable target that has been established is that 80% of the students score 80% or better on these presentations, and the ideal target is that at least 90% of the students will score 80% or better on their presentations. These targets have already been met for the classes in which the process has been implemented.

Summary

Student small group projects in online courses can be made as effective as small group projects in onsite courses using a process in which small groups prerecord their presentation for posting to all students in the online class. This approach surmounts the requirement that every member of the small group participate “live” in a particular online synchronous session where their presentation is made, overcoming the fact that work or family obligations can make it impossible for small group members to attend real time synchronous sessions. The process involves producing a short streaming video presentation using simple Microsoft PowerPoint™ tools that are easy to learn and widely available. The coordination that takes place during the production process enhances engagement of the students by developing a sense of community among the small group members. Easy to use tools in the Blackboard Learning Management System provide excellent ways for small group members to exchange ideas and work together on a common goal.

In the classes where this approach has been used, students have done a good job of refining and rehearsing their presentations during the production process. This leads to self-reflection as well as improved quality. The resulting presentations can be more polished than small group presentations in onsite classes. The whole class gets engaged with the small group projects through use of an online threaded discussion question in which every member of the class is required to listen to one small group presentation other than their own group, and then discuss whether or not they agree with the findings of the other small group and why.

A comprehensive rubric provided in advance to students makes expectations clear, and helps students understand how to improve their next presentation. A written assessment, based on the rubric, emphasizes positive feedback to encourage students and help them grow in their presentation skills. Enthusiastic student comments show that they find the process engaging and that the projects help them learn both the subject they are studying and how to work with the other members of their small group towards a common goal.

Appendix A – Grading Rubric for Small Group Presentations

Small Group Presentation Grading Rubric	Exceptional	Very Good	Good	Above Average	Average	Fair	Poor
	96%-100%	90%-95.99%	85%-89.99%	80%-84.99%	75%-79.99%	70-74.99%	less than 70%
Quality of Research	Eight or more relevant findings from research other than the textbook are discussed and compared	At least six relevant findings from research other than the textbook are discussed and compared	At least four relevant findings from research other than the textbook are discussed	At least two relevant finding from research other than the textbook is discussed	nothing other than the textbook discussed	Some points from textbook discussed	No evidence of any research
Original Thinking	At least seven new ideas are introduced and their relevance discussed in-depth	At least five new ideas are discussed and their impact is explored.	At least five new ideas are discussed.	At least three new ideas are discussed.	At least one new idea is discussed.	One idea from textbook is discussed.	No evidence of original thinking.
Understanding of subject	Extensive analysis backed up by specific citations to research findings	Extensive analysis demonstrates understanding of subject.	Some analysis is provided, demonstrating understanding of subject.	Good understanding of the subject is evident in multiple sentences.	Some ability to apply understanding of the subject is evident.	Minimum understanding of the subject is evident.	No evidence of understanding of the subject.
Thorough-ness of sources	At least eight references; they are cited throughout as well as at the end.	At least six references; they are cited throughout as well as at the end.	At least five references; they are cited throughout as well as at the end.	At least four references provided at end.	At least two references provided at the end.	Only one reference (other than the textbook).	No references given.
Organization of material	Outstanding organization between and within each section with multiple parts clearly identified; strong logical flow of ideas within each section from one section to the next.	Very good organization between and within each section with multiple parts clearly identified and good logical flow of ideas within each section.	Multiple parts clearly identified with good logical flow of ideas from one section to the next.	Good logical flow of ideas.	Some logical progression of ideas.	Haphazard organization.	No organization evident.

Effectiveness of presentation	Extensive excitement and discussion involving five or more members of the class, and presenters draw additional conclusions as a result	More than two persons engage in active discussion and presenters draw additional conclusions as a result.	More than two persons engage in active discussion with the presenters.	At least two persons ask questions, followed by class discussion.	At least one person asks a relevant question, followed by class discussion.	Minimal discussion of presentation by class.	No discussion generated from class
Thorough-ness of material	All facts backed up with specific citations. All of the backup is highly credible.	All facts backed. All of the backup is credible.	All facts backed. Most of the backup is credible.	All facts backed up but some gaps still exist	Most facts are backed up. No major gaps.	A few facts are backed up but there are major gaps	No facts are backed up.
Length of presentation	12 minutes plus or minus 1 min	10 minutes plus or minus 1 min	8 minutes plus 1 min or minus 30 sec	7 minutes plus or minus 30 seconds	6 minutes plus or minus 30 seconds	5 minutes plus or minus 30 seconds	less than 4 and a half minutes
Quality of Charts	Exceptional charts with no spelling errors, no more than 7 words per bullet, plus at least four excellent pictures and/or graphics that are clearly relevant and amplify the presentation	Very good charts with no spelling errors, no more than 7 words per bullet, plus at least three pictures and/or graphics that are clearly relevant	Minimal misspelling and grammar errors but meaning is clear. Concise words and no point with more than 7 words on a chart. At least two relevant pictures or graphics.	Minimal misspelling and grammar errors but meaning is clear. Concise words and no point with more than 7 words. At least one relevant illustrations	Minimal misspelling and grammar errors but meaning is clear. Concise words only. At least one illustration.	Multiple misspelling and grammar errors but meaning is clear. Words only.	Many misspellings and grammar errors. Hard to understand. Words only.
Quality of verbal presentation	Strong preparation. Points flow well for each presenter and across presenters. Excellent confidence; very persuasive	Strong preparation. Points flow well for each presenter and across presenters. Strong confidence.	Evidence of good preparation. Points flow well for each presenter but not across presenters. Good confidence.	Evidence of good preparation, but points do not flow well. Some confidence.	Some evidence of preparation. Some confidence.	Some evidence of preparation, but no confidence.	No evidence of preparation. Lack of confidence.

Appendix B – Example of Detailed Assessment of a Small Group Presentation

Original Thinking		X					
Understanding of subject		X					
Thoroughness of sources			X				
Organization of material		X					
Effectiveness of presentation	X						
Thoroughness of material	X						
Length of presentation			X				
Quality of Charts	X						
Quality of Verbal Presentation		X					
Total	3	5	2				
Comments	Very good work! You did a lot of very good research. Great quote from John Adams. Also great illustration showing the pyramid with Maslow's hierarchy of needs. This really made your point on that chart very effectively. Your discussion demonstrated very good original thinking and understanding of the subject. You showed four sources at the end, and you cited them throughout the presentation. The material was very well organized and easy to follow. The additional alternative of doing a pilot project, that came out of the discussion following your presentation was excellent. Thoroughness was excellent; all facts were backed up with specific citations. All of the backup is highly credible. Length of presentation was approximately 8 min 15 seconds which is good. Quality of charts was excellent. And the verbal presentation was very good, showing strong preparation. Points flowed well for each presenter and across presenters, and presenters demonstrated strong confidence.						

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Engaging Community College Students in Engineering Research through Design and Implementation of a Human-Machine Interface for Gesture Recognition

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Abstract
The role of community colleges in undergraduate education is very important for individuals from groups traditionally underrepresented in the science, technology, engineering, and mathematics (STEM) fields. Engaging community college students in cutting-edge STEM research is a significant strategy for inspiring students' interest in STEM and increasing the recruitment and retention of STEM students. With support from the NASA Creating Opportunities for Minorities in Engineering, Technology, and Science (COMETS) Internship Program, in summer 2015, four sophomore engineering students from Cañada College, a Hispanic-Serving community college in California's Silicon Valley participated in a ten-week summer research internship project on the development of an intelligent human-machine interface (HMI) for gesture recognition in a research lab at San Francisco State University, a public comprehensive university. This internship project aims to develop a software research platform for gesture recognition by interfacing with a commercial armband called Myo (Thalmic Labs), which measures signals from eight EMG sensors and an inertial measurement unit (IMU). The developed software platform provides a user-friendly GUI that is able to collect raw EMG and IMU streaming data from the Myo armband, extract useful features from the raw data, recognize user's gestures in real-time by using various pattern classification methods, and provide visual feedback to the user. The developed modularized software can be used as a basic research platform for gesture recognition, which can be easily expanded in many ways including applying various feature extraction methods and pattern classification algorithms, and interfacing with gesture-controlled applications and devices. The project provided a great opportunity for the student interns to learn valuable engineering knowledge and skills as well as improve their skills in teamwork, communication, writing, presentation, and time management. The outcome of this project indicated that the summer research internship program was an effective method for engaging community college students in engineering research and strengthening their confidence and interest in pursuing an engineering profession.

Introduction
There is broad consensus that an adequate supply and quality of workers in the science, technology, engineering, and mathematics (STEM) fields is essential to continued U.S. economic competitiveness and growth. The role of community colleges in undergraduate education is very important for individuals from groups traditionally underrepresented in the STEM fields. Engaging community college students in cutting-edge STEM research is a significant strategy for inspiring students' interest in STEM and increasing the recruitment and retention of STEM

students. With support from the NASA Creating Opportunities for Minorities in Engineering, Technology, and Science (COMETS) Internship Program, in summer 2015, four sophomore engineering students from Cañada College, a Hispanic-Serving community college in California's Silicon Valley participated in a ten-week summer research internship project on the development of an intelligent human-machine interface (HMI) for gesture recognition in the Intelligent Computing and Embedded Systems Laboratory (ICE Lab) at San Francisco State University (SFSU), a public comprehensive university. The student interns were mentored by a faculty advisor and a graduate student from SFSU.

Gesture recognition is a method to improve the intuitiveness and efficiency of direct communication between humans and technology. It is instrumental to applications such as human-assisting robots, rehabilitation devices, and virtual input devices. Surface electromyography (EMG) is a technology that measures muscle activities by using electrodes placed on the skin. EMG signal has been found an effective bioelectrical signal for expressing movement intention and widely studied for gesture recognition. However, it is still an underdeveloped field with few robust and reliable mobile gesture recognition platforms commercially available. This internship project aims to develop a software research platform for gesture recognition by interfacing with a commercial armband called Myo (Thalmic Labs), which measures signals from eight EMG sensors and an inertial measurement unit (IMU). The developed software platform provides a user-friendly GUI that is able to collect raw EMG and IMU streaming data from the Myo armband, extract useful features from the raw data, recognize user's gestures in real-time by using various pattern classification methods, and provide visual feedback to the user. The developed modularized software can be used as a basic research platform for gesture recognition, which can be easily expanded in many ways including applying various feature extraction methods and pattern classification algorithms, and interfacing with gesture-controlled applications and devices. The project provided a great opportunity for the student interns to learn valuable engineering knowledge and skills as well as improve their skills in teamwork, communication, writing, presentation, and time management. The outcome of this project indicated that the summer research internship program was an effective method for engaging community college students in engineering research and strengthening their confidence and interest in pursuing an engineering profession.

Project Design and Experimental Results

Background. Given that there are an infinite number of movements that a human body can execute, guidelines need to be set when selecting a set of gestures in any given application. Gestures need to be intuitive for the situation; a user must not need to memorize an unusual set of gestures that do not match the context of their usage. Gestures should be natural for humans to perform and not cause users to contort their bodies in painful ways. When creating a gesture recognition platform, the selected gestures to be recognized need to be intuitive yet unobtrusive, as well as distinctly different from normal muscle movement.

For gesture recognition, many different classification algorithms have been studied. Wheeler suggested using Hidden Markov models (HMM) because of its high rate of success. HMM assumes the presence of a Markov process with hidden states. This model makes predictions without knowing the full history of the process the model is classifying. This particular study also recommended using the Viterbi algorithm of 1967 for classification with relatively good success (Wheeler, 2003). Chen and Wang suggested multiple classification algorithms with varying amounts of success (Chen & Wang, 2012). The *k*-Nearest neighbor (KNN) algorithm classifies using a majority vote amongst its neighbors. For gesture recognition, however, KNN does not have high success. Linear discriminant analysis (LDA) and quadratic discriminant analysis (QDA) operate in similar manners, where a projection with maximum difference between classes is created. In LDA, the division between categories is created with lines, while QDA uses quadratics to divide categories. Multiple kernel learning (MKL) creates kernels using observed features, in order to identify a gesture based on one composite kernel instead of multiple features. Support vector machine (SVM) uses aspects of MKL and operates on a similar level to LDA and QDA. SVM, however, allows projection on an unlimited amount of dimensions and indicates divisions using hyperplanes. In this study, Chen and Wang recommended using MKL-SVM for accurate gesture recognition.

System Design. Figure 1 shows the overall architecture of the designed HMI for gesture recognition. Multiple channels of EMG signals from the Myo armband are the system inputs. The signals are segmented by overlapped sliding analysis windows. EMG features that characterize individual EMG signals are then extracted for each analysis window. To recognize the user's gesture, EMG features of individual channels are concatenated into one feature vector and then sent to a pattern classifier for gesture recognition. The pattern classification algorithms generally consist of two phases: training and testing. In the training phase, a set of EMG data are collected from each investigated gesture to create a classification model that maximally distinguishes the EMG patterns of different gestures. In the testing phase, the feature vector extracted from new incoming EMG signals is sent to the trained classification model for a decision to identify the user's current gesture in real-time.

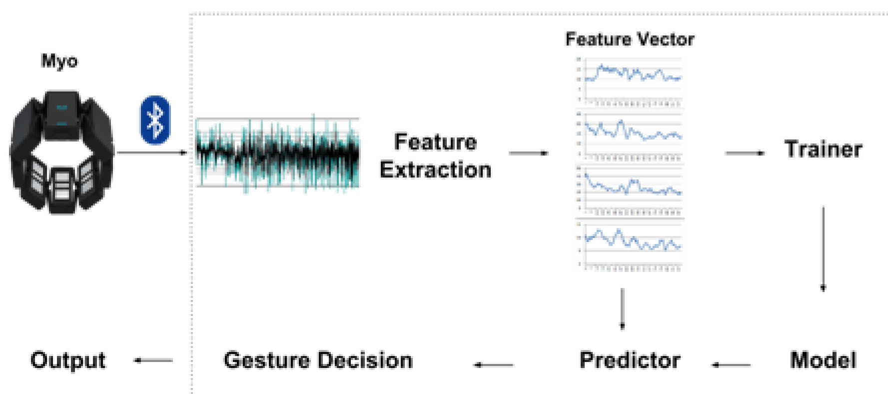

Figure 1. Overall architecture of the designed HMI for gesture recognition

EMG Data Collection. EMG is a procedure used to assess electrical activity produced by skeletal muscles. EMG signals measure electrical activity, normally as a function of time, which is defined in terms of amplitude, frequency, and phase. The EMG signal collection device used in this project is called Myo Armband made by Thalmic Labs. The Myo armband utilizes surface electromyography (sEMG), a technique in which an electrode is placed on the skin, to process data. Specifically, it has eight EMG sensors, each of which streams a unique signal at 200 Hz. Additionally, it has an integrated inertial measurement unit (IMU) including three-axis gyroscope, three-axis accelerometer, and three-axis magnetometer, each of which streams data at 50Hz. Through a Bluetooth 4.0 Low Energy connection, EMG and IMU data can be streamed to any compatible device, which in this project was a Windows PC. Throughout these experiments, the Myo armband was worn on the forearm of the user and used as the main device to collect necessary data for the HMI.

Selection of Features. For feature extraction, five different methods are implemented by analyzing sets of EMG data, or analysis windows, over a period of time. The user-defined number of data points per window is known as window length. Each window is collected with a user-defined number of new data points, called window increment. To avoid data loss, window increment is always less than window length. For the purposes of normalization, the sum of each feature value is divided by the total number of samples. The Hudgins' time-domain features include mean absolute value (MAV), waveform length (WAVE), zero crossing (ZERO), and slope sign change (TURN) were used in this project (Hudgins, 1993). Another method employed was the mean mean absolute value (MMAV). The MMAV feature, as described in (1), is utilized to detect motion or active signals during the training of the classifier. To employ this feature, the signals from each channel, c, are summed and divided by the total number of channels, C. If the MMAV crosses a user-defined threshold, the feature data will pass as training data to the classifier, otherwise the training data is left unchanged.

$$MMAV = \frac{1}{C}\sum_{c=1}^{C} x_c(t) \tag{1}$$

The MAV feature, as described in (2), summates the magnitude of the signal from every channel in each window. The MAV is useful for detecting when the user is performing a gesture or not performing a gesture, and the certain channels that the MAV is spiking on reflects a pattern based on what certain gesture is being performed. The WAVE feature, as described in (3), is similar to MAV except the difference in magnitude between one data point and the preceding data point is summated, giving an estimated waveform length of the EMG data values over time. The WAVE is useful for detecting the pattern that a gesture creates in the EMG data regardless of the magnitudes of their values. The MAV and WAVE can be normalized by calculating the average of all eight channels and dividing the summations by that average.

$$MAV = \frac{1}{N}\sum_{k=1}^{N} |x_k| \tag{2}$$

$$WAVE = \sum_{k-1}^{N} |x_k - x_{k-1}| \quad \textbf{(3)}$$

The ZERO feature, as described in (4), calculates a frequency based on the number of times the waveform crosses zero. Similarly, the TURN feature, as described in (5), calculates a frequency based on the number of times the slope changes its sign from positive to negative or vice versa. These features both generate unique values based on the gestures being performed, which assists in differentiating between gestures. In both of these features, a user-defined threshold is set to reduce noise or insignificant data.

$$(x_k > 0 \text{ and } x_{k+1} < 0) \text{or } (x_k < 0 \text{ and } x_{k+1} > 0), \text{and } |x_k - x_{k+1}| \geq threshold \quad (4)$$

$$\begin{gathered}(x_k > x_{k-1} \; and \; x_k > x_{k+1}) \; or \; (x_k < x_{k-1} \; and \; x_k < x_{k+1}) \\ and \\ (|x_k - x_{k+1}| \geq \text{threshold}) \; or \; (|x_k - x_{k-1}| \geq \text{threshold})\end{gathered} \quad (5)$$

Overall, the Hudgins' time domain features were used to process the raw EMG data while the MMAV was used to determine active states.

Selection of Classification Algorithm (Classifier). In this project, the SVM classification method was adopted because of its previous success in EMG pattern recognition (Chen & Wang, 2012). SVM is a supervised learning model that analyzes data patterns and is able to perform both linear and non-linear classification (performed using a kernel method). SVM operates by representing data points in a high-dimensional space that separates categories with the widest, clearest gaps possible, represented by hyperplanes referred to as support vectors (Hsu, Chang, & Lin, 2003). The implementation of the SVM algorithm was based on LIBSVM, an open-source SVM based library (Chang & Lin, 2011). LIBSVM supports two-different support vector classification methods: C-SVC and NU-SVC as well as four different kernels types including *linear*, *polynomial*, *radial basis function (RBF)*, and *sigmoid*. The implemented SVM algorithm consists of two major phases: data preprocessing and model selection. The data preprocessing phase transforms and scales the collected EMG data to make sure that the LIBSVM library is able to understand the data. The model selection phase selects the classification method, the kernel type, and configures required parameters for the classification method.

Development of the Graphic User Interface. In this project, a friendly graphic user interface (GUI) was implemented in C++/CLI using Microsoft Visual Studios. The Graphical User Interface (GUI) consists of six tabs: *Input*, *IMU*, *EMG*, *Feature Selection*, *Classifier*, and *Output*, each having its own function. The software was written with flexibility in mind, so that additional methods of feature extraction, classification, and various EMG devices can be seamlessly integrated. The *Input* tab, as shown in Figure 2, provides information relating to the Myo configuration and connection options. Firstly, the user has the ability to control connections for up to two Myos, start and stop streaming of data from the device(s), and ping a specific Myo to identify it. Further, the battery level and connection status of each Myo is displayed. While streaming from the Myo armband(s), there is an option to record the data to a file simultaneously. While recording, a button allows adding a "marker" to the file. This way the saved data can be reviewed and analyzed separately while having markers to help organize. Lastly, the saved files can be opened to playback and stream data without the Myo armband(s). The first tab is most useful when controlling the device and managing data.

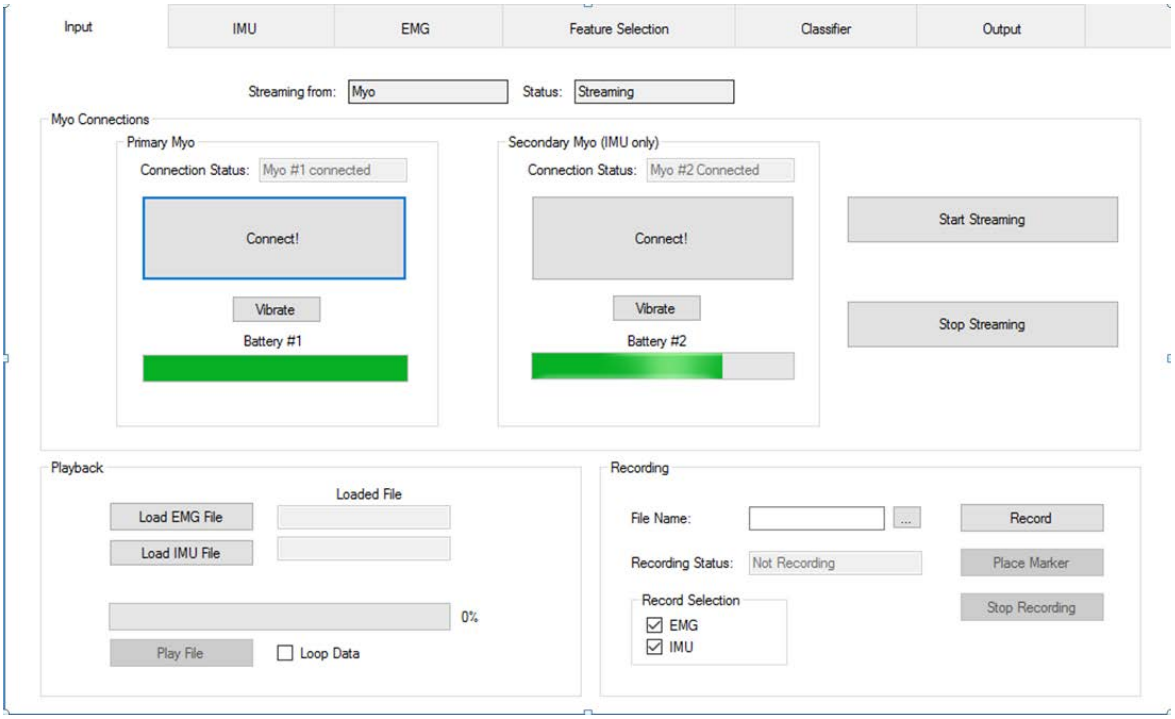

Figure 2. The *Input* tab showing the status of two Myo bands connected.

The *IMU* tab displays data relating to the IMU measurements. More specifically, it has two graphs that the user can customize to display orientation, accelerometer, or gyroscope data from both Myo armbands. In addition to the graphs, there is a column of boxes that displays raw IMU data as it is being streamed at 50 Hz. The IMU tab is most helpful when performing a dynamic gesture that is dependent on the movement of the Myo armband and when extracting features from the orientation data.

Figure 3. The *IMU* tab displaying the orientation plot of both connected bands as well as the raw data of the primary Myo band.

The *EMG* tab, as shown in Figure 4, displays data relating to EMG and provides control relating to feature extraction. Firstly, there are eight boxes, each corresponding to an EMG channel, which display raw EMG data as it is being streamed. Then, there are three graphs, two radar

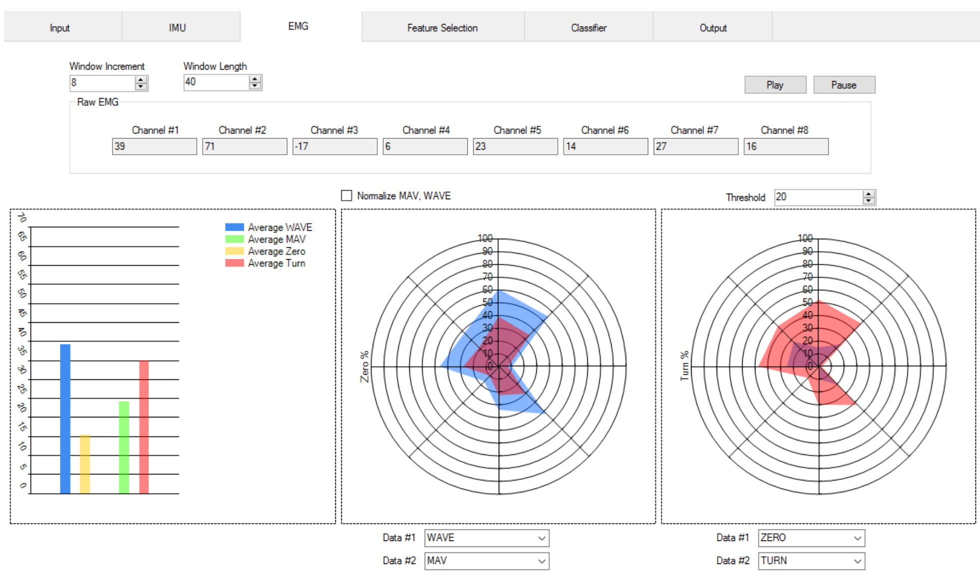

Figure 4. The *EMG* tab graphing four methods of feature extraction and displaying raw EMG

graphs and one bar graph, which display feature data as it is being calculated in real time. The radar format provides an easy way of analyzing eight sets of MAV, WAVE, ZERO, or TURN data relative to the location of the sensors on the arm. The user has the option to normalize the MAV and WAVE feature data and to adjust the threshold for the ZERO and TURN features. The window length and window increment are set to a default value of 8 and 40 respectively, but can be adjusted to manipulate feature extraction. The EMG tab can be used to adjust variables and to simply examine the feature data when performing a certain gesture.

The *Feature Selection* tab allows the user to select which feature data to use in the classifier. This functionality allows the user to test different features and their impact on gesture recognition accuracy. On the other hand, the *Classifier* tab as shown in Figure 5 can be used to record custom gestures and use the classifier to predict the current gesture in real time. This tab displays a MMAV over time graph and IMU graph to make it easier for the user to record the gesture. The user is able to name the custom gesture, choose where to save the files relating to the classifier, and choose specifically which classifying method to use. Finally, the feature selection and classifier tab can be used to test the effectiveness of different feature extraction and classifying methods.

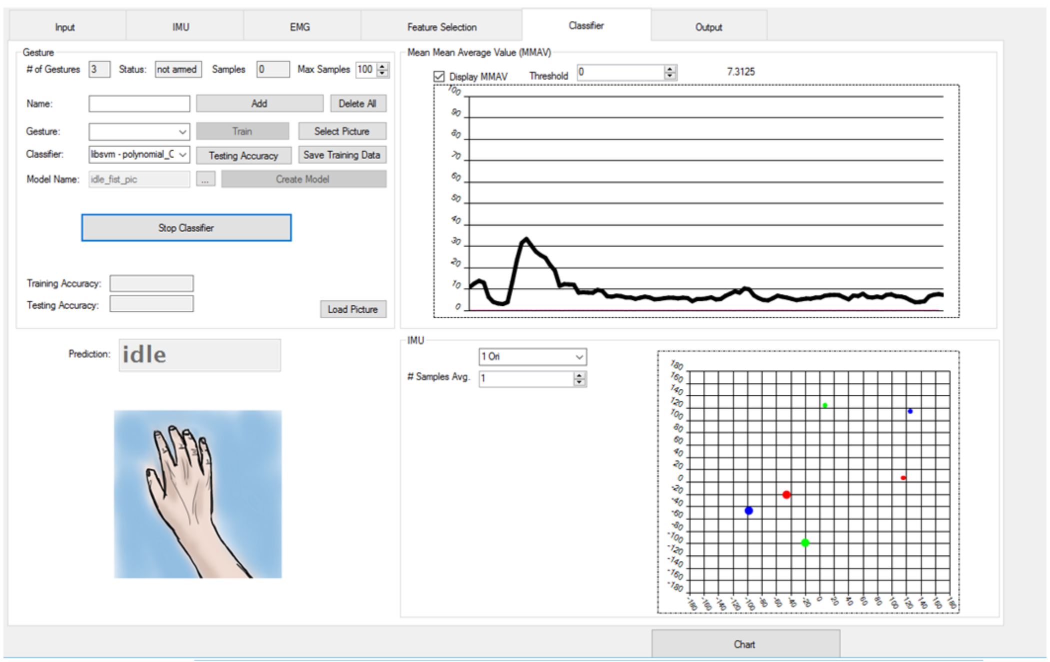

Figure 5. The Classifier Tab with classifier correctly predicting custom idle gesture.

Experimental Results and Future Work

To evaluate the performance of the developed HMI for gesture recognition, six subjects were recruited, four male and two female. For each subject, six gestures were investigated including idle, fist, wave in, wave out, thumb up, and point (Figure 6). Four EMG features including WAVE, MAV, ZERO, and TURN were extracted from raw EMG signals and the SVM models with two classification methods (C-SVC and NU_SVC) and three kernel types (linear, polynomial, and RBF) were tested for pattern classification. Each subject wore one Myo armband on his/her dominant forearm and performed each gesture until 100 samples of feature vectors were collected. The collected data was split into two sets. Each of these two sets was trained to create a classification model and then tested on the other set. The testing accuracies of the two sets were then calculated and averaged. Table 1 shows the testing accuracy of each SVM model for each individual subject. The bottom row shows the testing accuracy averaged across six subjects. Overall these percentages suggest that models linear_C, poly_C, and linear_NU were most accurate in recognizing the gesture set chosen. However, each kernel had a high variance between different subjects and even between different trials between the same subjects, ranging from 40-50% to 90-100%. More subjects would be beneficial to establish a clearer range of variance values within each kernel.

In conclusion, the developed HMI platform for gesture recognition successfully incorporated the selected feature extraction and classifier methods to deliver accuracy readings based on a six-

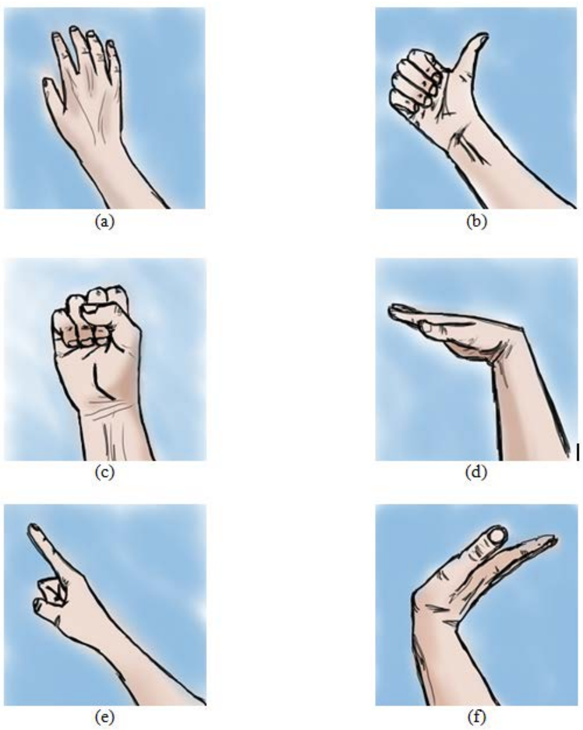

Figure 6. Gestures used for testing the abilities of the human-machine interface. Gestures depicted: (a) "idle, (b) "thumbs up", (c) "fist, (d) "wave in", (e) "point", and (f) "wave out".

gesture data set. This is proven by the platform's ability to record multiple custom gestures and accurately predict each gesture in real time. The usage of the LIBSVM library in this project can be further optimized by using cross-validation to select the best parameters for accurate classification. The HMI can be further developed with the addition of different methods of feature extraction and classification and different devices. Further, feature extraction methods for IMU data can be implemented which can allow for recording and predicting dynamic gestures relating to movement. Moreover, the Myo armband itself can be supplemented or replaced with a similar device to analyze EMG signals from different parts of the body that can potentially expand functionality and applications.

Table 1. Testing results of the developed NMI for gesture recognition

	linear_C	poly_C	RBF_C	linear_NU	poly_NU	RBF_NU
Subject #1	99.7%	96.7%	33.3%	54.5%	86.8%	33.3%
Subject #2	53.0%	96.2%	17.5%	97.0%	93.3%	28.5%
Subject #3	98.8%	97.2%	33.5%	98.0%	46.5%	33.5%
Subject #4	99.0%	96.8%	18.2%	98.7%	87.8%	18.3%
Subject #5	99.8%	98.8%	26.8%	99.3%	54.2%	24.0%
Subject #6	89.7%	48.7%	27.2%	87.3%	44.8%	26.8%
Testing Average	90.0%	89.1%	26.1%	89.1%	68.9%	27.4%

Project Assessment

A post-program survey was conducted for all sixteen students participating in the COMETS program including another twelve students in the mechanical, electrical, and civil engineering. Table 2 summarizes the results of the survey on student perception of skills learned from participating in the program. The results for questions designed to measure perception of over-all usefulness of the research internship program are shown in Table 2.

Table 1. Summary of student responses to the post-program survey measuring the perceived benefit of participating in the research internship program.

Question: As a result of your participation in the program, how much did you learn about each of the following? 1 – Nothing; 2 – A little; 3 – Some; 4 – Quite a bit; 5 – A lot.

Activity	Average Rating
Performing research	4.81
Designing/performing an experiment	4.75
Creating a work plan	4.63
Working as a part of a team	4.63
Writing a technical report	4.75
Creating a poster presentation	4.69
Making an oral presentation	4.81

Table 2. Summary of student satisfaction with the summer research internship program.

Question: Tell us how much you agree with each of the following statements. 1 – Strongly Disagree; 2 – Disagree; 3 – Neutral; 4 – Agree; 5 – Strongly Agree.

Activity	Average Rating
The internship program was useful.	4.69
I believe that I have the academic background and skills needed for the project.	4.38
The program has helped me prepare for transfer.	4.31
The program has helped me solidify my choice of major.	4.13
As a result of the program, I am more likely to consider graduate school.	4.13
As a result of the program, I am more likely to apply for other internships.	4.75
I am satisfied with the NASA CIPAIR Internship Program.	4.50
I would recommend this internship program to a friend.	4.63

For the group of students working on the development of HMI for gesture recognition, their responses to the question "what do you like most about the Internship Program? Please write any comments or suggestions you have on the program." include: "I like the environment that the COMETS internship program put us in. I liked the structure with having a student mentor and faculty advisor." "I greatly appreciate the opportunity - I was really excited to learn more about classification algorithms that happen to be a part of my future studies!" "Thank you! This has been an incredible experience for someone who has never done an internship before or any kind of independent research."

Summary and Conclusion

The research internship project was successful in helping community college students learn valuable engineering knowledge and skills as well as gain research experience in emerging computer engineering and HMI fields. The project provided a great opportunity for the students to improve their skills in teamwork, communication, writing, presentation, project management, and time management. The outcome of this project indicated that the summer research internship program was an effective method for engaging community college students in engineering research and strengthening their confidence and interest in pursuing an engineering profession.

Acknowledgement

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WORK-IN-PROGRESS

Teaching Software Engineers to Write by Telling Them They Already Know How (Work-in-Progress)

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Abstract
In the Computer Science and Software Engineering programs at Cal Poly SLO, we require students to take a course in Professional Responsibilities. (2015-2017 Cal Poly Catalog 2016). In particular, the students must write a research paper that applies the IEEE/ACM Software Engineering Code of Ethics to a real current problem in computing and software. The paper requires a 4,000-word research writing. This includes an abstract, the basic facts, a research question, a social implication from the question, previous work and logical analysis that lead to an answer. The logical analysis section requires the students to apply Software Engineering Code tenets to the facts to exhibit a solid conclusion. The research writing skills required are considered so important to the CS department that students cannot pass the course itself without a passing grade on this paper. Over several years of development of the specification for this paper, the Instructor has found recurring weaknesses in the students' ability to write up research well. Typical errors include utilization of multiple terms for the same concept, not defining critical concepts before using them, and writing paragraphs that exhibit several different ideas rather than focusing on one at a time. Even though remedial instruction and exercises were executed, the errors remained, even though the students were capable of higher quality research writing. What was keeping these students back? We've observed that the students were mostly trained in "persuasive" or "essay" writing styles. Such writing styles can interfere with students' objective research writing, leaving them frustrated and thinking that, "writing this stuff is hard!" They often express the notion that objective, clear research writing is not a skill they'll ever need. They believe that computer science students have no use for this skill. Many students hardly try and others are slowed by a belief that it is yet another difficult, useless skill to learn. We'd like to disabuse them of these beliefs by easing the transition from program writing to research writing.

Background

Several years ago, the instructor taught programming and software requirements engineering classes. The students in those classes had to produce documents and programs that were clear, unambiguous, and useful as a reference for future readers. While advising them of program writing qualities, the instructor observed that the research writing and program writing exhibited very similar errors. Could they have common solutions? We hypothesize that if we can build the right map from the domain of program writing errors onto the domain of research writing errors, then we can devise a corresponding map from program writing solutions onto research writing solutions. Preliminary work on this hypothesis develops a mapping (map 1) from program writing errors onto the corresponding research writing errors. Next, we define the known map (map 2) from the program writing errors onto the program writing solutions. Naturally, at this stage, we'll apply map 1 from program writing solutions onto research writing solutions. This provides our hypothesis test: does map 1 facilitate significant improvement in research writing? Anecdotal evidence for significant improvement has been observed. The current work seeks to test whether such improvements are indeed significant and, if so, by what measure.

If we find significant improvement, we believe that these maps can leverage the students' extant program writing knowledge to improve research writing skills. Exhibition of the map will serve to demythologize the task of research writing for students. The maps have the potential to save both students and instructors significant time and effort while simultaneously improving the quality of the work. The rest of this work will go over the basics for three sample partial maps. The first basic error in program writing is variable naming. If a variable name has only a general relationship to its contents or type, then the code itself exposes less of the important semantics needed to perform testing, debugging and maintenance. Suppose a programmer needs a variable to represent the velocity of a car. A good name for that variable could be 'speed,' a poorer choice in name could be 'motion'. The name 'motion' conveys less information than the specific name 'speed' to the reader. If another programmer sees 'motion' they must spend time and effort to fully understand what it represents. To prevent this, programmers are taught at the elementary level to name variables as descriptively as possible. When done well, any programmer working on the code can quickly and easily understand what the variable represents. (Incremental Java Descriptive Variable Names 2016).

In the context of research writing this problem can appear when a concept is named more abstractly than necessary. Research writers consider precise communication of semantics to be of primary importance. Therefore, names for research concepts must as specific as is possible. When writing a research paper a name for a term must be narrowly defined prior to its use. Doing this relieves the reader of ambiguous guesswork. This mapping may assist the programming student in writing more precise concept names. This mapping illustrates the fact that programmers already have the skill to convey semantics directly through their program variable naming skills. We hope that if the students apply this programming skill to research writing that the ambiguity in their writing will be greatly lessened. The next basic programming error occurs when two distinct variable names refer to the same concept. Two distinct variables can hold two distinct values. However, these variables refer to the same underlying value in the domain. Depending on when and how a given variable is updated the two may not agree in value. So the accuracy of the results depends on which variable is used. The resulting bug takes significant effort through investigation to eliminate the ambiguity. Ultimately, the programmer finds that having two variable names for the same concept is expensive to fix. If the programmer had used a single value for a single concept the error disappears.

When writing up research, an author may use two different abstract terms to describe the same concrete domain concept. In this case, the reader will encounter ambiguity when trying to understand the intended semantics. As an example, the words 'private' and 'confidential' could be used interchangeably in reference to describe data behind iPhone encryption. Readers looking for precise semantics will find this confusing. Why did the writer introduce two terms unless they intended to introduce two distinct concepts? Just like the programmer who creates two variables for the same data, these two words introduce ambiguity for readers trying to understand intended semantics for a single concept. Our work on this map is designed to reduce the amount of confusion about the writer's intended semantics. In persuasive and essay writing students are taught to change up their language to keep readers interested. (13 Ways to Make Your Writing More Interesting to Read 2014. Students in the Professional Responsibilities course complain that they have consistently used this style of writing that requires such variations in terms. Their instincts now tell them to vary the use of terms in order to please the reader. A research paper has the purpose of conveying precise semantics. Our goal is to utilize this mapping to illustrate that they already know the value of using a single term to reference a single concept.

The last and possibly most important programming error is unoptimized code, which can be created by many different factors but the main one is that programmers are human. Programmer's first instincts about how to write a piece of code aren't always the correct way and if the programmer never looks back at the code many errors could arise. Some of these errors include slow load times or bugs that create the program unusable. Programmers many times need to go back through their code and fix these errors because they do not notice them the first time, or that these variables meanings got changed while the programmer was working on it and can be written in a better way. The solution is to 'refactor' the code. Refactoring is when a programmer "improves" the 'quality' of the code. Quality, in this instance, refers to readability, understandability, maintainability and efficiency of that code. The function the code implements is unchanged. Programming students are taught that every time they "touch" a piece of code they must leave it a little better than when they entered it. This is an incremental improvement technique for programmers.

In research writing, incremental improvements are made by drafting. Drafting for writers forces them to work on their existing product and improve it through techniques like proof reading. This drafting process helps authors find errors they have made, such as spelling, grammar, or logic. They can make incremental corrections and improvements in this process. This mapping will show computer science and software engineering students that drafting while writing papers is a necessary process with which they are already familiar. Students writing the paper for the Professional Responsibilities course make elementary errors that show they do not draft much. They only work on drafts just before the due date. These same students would not even think of turning in a programming assignment without going over it first. It would not compile or work in any way. We believe that the students, understanding that they already learned the refactoring skill, will translate that skill to drafting and incrementally improving their research writing. The entire purpose of this work is to convince computer science and software engineering students that they already have the critical skills required to produce high-quality research writing. We will do this by showing the maps to the students so that they can apply their programming skills appropriately to research writing. In the end, we hope to generalize this work beyond just our students. We intend to publish incremental results in order to receive criticism, make connections and improve the work.

We thank ASEE-PSW for providing a vehicle for us in this endeavor.

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Instructables.com as a Tool to Improve Student Outcomes and Promote Community Engagement (Work-in-Progress)

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Abstract
Project-based Learning (PBL) has become a popular pedagogical tool in Engineering. Projects force students to put theory learned in lecture into practice, exposes students to some of the non-idealities of real systems (imperfect instruments, uncooperative systems, etc.) that are difficult to convey in lecture or homework, and ideally motivates students by showing how course material is related real-world engineering problems. This work discusses my preliminary and ongoing research into using Instructables.com—a user-content generated website of "Do It Yourself" tutorials—as a tool to help amplify the benefits students derive from PBL. Specifically, I require students to document their projects in an Instructable in lieu of a final report, and I encourage students to post their Instructable to Instructables.com. This work discusses three ways in which the use of instructables.com may improve PBL outcomes. First, instructables.com may improve students' motivation for pursuing further study in the field of engineering. This belief is rooted in the framework of Self Determination Theory, which stresses the importance of a task's "Relatedness" for developing intrinsic motivation. By using instructables.com as a motivation for project ideas and as a publication venue for project results, students can see how their work relates to work being done outside of academia. Second, by requiring students to write a step-by-step tutorial of their final project, the use of the "Instructable" format encourages students to reflect on their designs and design decisions, potentially improving student outcomes. Finally, this work briefly touches on how encouraging students to document their designs on instructables.com may lead to more interaction between the "maker" and engineering communities, thereby enhancing public awareness of the Engineering Profession.

Introduction

Project-based learning (PBL) is a well-established tool in Engineering Curricula. Many programs incorporate senior or capstone design courses to give students realistic design experiences, and an increasing number of programs offer "cornerstone" design experiences at the freshman levels (Dym, Agogino, Eris, Frey, & Leifer, 2005). Among other considerations, Project Based Learning is thought to help improve motivation and retention rates among students (Atadero, Balgopal, Rambo-Hernandez, & Casper, 2014; National Academy of Engineering, 2005), and the National Academy of Engineering recommends early exposure to design practice, including PBL, to improve engineering education (2005).

While by itself PBL offers enormous benefits to student learning, it is likely that how a project is administered can serve to amplify or diminish these effects. This work explores the use of Instructables.com as a tool to help maximize the benefits students glean from project-based learning. Instructables.com is a user-content generated "Do-it-yourself" (DIY) site. Any user can submit an Instructable—a step by step tutorial for completing a project—and the site contains

Instructables for over 100,000 projects (Instructables.com, 2016) on a variety of topics. All Instructables are visible to the entire Instructables.com community, where other users are able to view, “favorite,” and comment on the project. Comments left on a specific Instructable are subject to a “Be Nice” comment policy, that instructs users to be positive and constructive in their feedback.

This paper first analyzes the use of Instructables.com through the framework of Self-Determination Theory (SDT) (Ryan & Deci, 2000) to explore in detail how it can theoretically aid student motivation and retention. I then touch on the use of Instructables.com as a tool that helps foster student reflection and increases interaction between Engineering students and the broader Maker/Hobbyist community. In these discussions, I primarily focus on the use Instructables.com as a medium for students to document their designs, but also discuss how Instructables can be used to help students appropriately scope open-ended projects.

Self-Determination Theory and PBL-Based Motivation

Self-Determination Theory explores the concept of motivation in individuals. At a basic level, SDT differentiates between two types of motivation, autonomous—completing tasks because one finds them fulfilling and worth doing—and controlled—completing tasks because one feels pressured to do them. People operating under controlled motivation are less likely to persist in a task once the external pressures are lifted. Therefore, to effectively promote retention in engineering, it is important that instances of PBL promote autonomous motivation in students. Self-Determination Theory states that there are three needs that must be met to foster autonomous motivation: competence, autonomy, and relatability (Gagné & Deci, 2005). I believe that Instructables.com and its affiliated user community can help a course project to meet these needs.

Feelings of competence can be impacted by both the perceived difficulty of a project, and by the feedback (s)he receives for completing a project. The literature often refers to “optimally challenging tasks” (Gagné & Deci, 2005, p. 332), or tasks that are scoped to encourage “stretching of one’s capacities” (Deci & Ryan, 1985, p. 27) as beneficial for improving autonomous motivation. Unfortunately, different students in the same class often have different levels of understanding of the material: To maximize students’ autonomous motivation, each group might need a slightly different project. For reasons of fairness and time, it would not be feasible for the professor to create custom project assignments for each group. An open-ended assignment that allows groups to choose their own projects within some guidelines helps mitigate these issues while providing students an increased sense of autonomy. In introductory courses, though, not all students may be familiar enough with the material to scope an appropriate project proposal. This is an area where Instructables.com can help: by showing students write-ups of a myriad of example projects, students can get an idea of how much effort is required to implement different types of systems. They can then use this information to scope a project appropriate for their level, setting them up for increased feelings of competence once the project is concluded. As an example of this, in the Fall of 2014, I required students in my introductory Digital Design course to build an electronic game on their FPGA. By looking through past projects on Instructables.com, students found an Instructable describing an FPGA implementation of Pong (Raja, 2014), which gave them critical insights both into the challenges involved with interfacing an FPGA to a VGA monitor, and the inspiration that they could actually make a video-game on an FPGA using concepts they already knew from class.

Studies show that praise and social approval can also increase feelings of competence (Deci E. L., Effects of Externally Mediated Rewards on Intrinsic Motivation, 1971): to maximize student motivation, good work must be rewarded with recognition. In a class setting, however, the desire for recognition may be difficult to meet. If a project assignment is narrowly scoped, there may not be much room for project differentiation among individual groups, so individual praise from a professor may be less impactful. If the project is open-ended, it may be the case that a few standout projects grab the attention of the professor and classmates, leaving many other very good projects unrecognized. Once again, Instructables.com can help mitigate this issue. If a student publishes their completed project to Instructables.com, they have the opportunity to receive feedback on their designs from the large Instructables community. Given Instructables.com's "Be Nice" comment policy, and its active group of moderators, in my experience, students have always received positive, competence enhancing feedback.

Finally, while some students might find a given class project intrinsically interesting, many are engaging in the project due to external motivation—namely the project grade. To get students to internalize motivation for the type of work featured in a final project, the task needs to promote a sense of relatedness, or belonging within a broader social context (Deci E. L., et al., 2001). While some of this need may be met by the professor and the cohort of classmates, these sources of relatedness are limited. Students may only have a given professor for one quarter, so any relatedness-promoting social relationship between student and professor may be too transient to affect student motivation. As class sizes and enrollments swell, there may be less of a cohesive social structure around a particular major's cohort, stymying the ability of this group to support relatedness. Additionally, some students in "required" courses may find the course and project subject matter outside of their area of interest, potentially meaning that the "social context" of the cohort places less value on a successful project. With its large community of active hobbyists, tinkerers, and makers, Instructables.com provides a social context where engineering students can talk about and find support for their creative, project-based efforts. In fact, students report that community members occasionally reach out to them to ask about their projects: "putting the final projects from CPE439 on Instructables was a pretty cool idea. It was overall more satisfying than most of my other final projects because now other people message me because they're interested in the project and want to recreate it, compared to my other projects that just live in my drawer and collect dust." This sort of continuous engagement from a community allows a course project to have a positive impact on students long after the quarter ends.

Combined, I believe that the joint effects of boosting feelings of competence and relatedness that come from having students interact with the Instructables.com community has the potential to leave students more autonomously motivated for completing digital design and embedded system-type projects, and persisting in these fields of study. The next step in this research will be to use survey instruments to attempt to quantify the extent to which Instructables.com really does elicit this effect in students.

Additional Benefits of Instructables.com as a Pedagogical Tool

In addition to improving student motivation, the use of Instructables.com in PBL may have the potential to improve student learning through reflection. Whether or not students choose to post their project to Instructables.com, they must still complete a step-by-step write-up that teaches an interested technical audience how to reproduce the system. This process causes students to look back over their design and clearly explain how and why they built their system the way they did, and also requires them to justify any assumptions they have made in constructing the system. Since engaging in critical reflection can improve learning (Boaud, Keogh, & Walker, 2013; Moon, 2013), it stands to reason that using Instructables.com in PBL similarly improves student learning. It is important to note, however, that students would only get the full benefits of reflection if they take Instructable writing seriously. To ensure that they do, I generally weight the final written Instructable as 30-40% of the overall project grade.

The other benefit of using Instructables.com to enhance Project Based Learning is that it increases the interaction between engineering students and the broader population. As an open community Instructables.com attracts hobbyists and “Do-it-Yourselfers” from a wide-range of backgrounds, including those with no formal training in engineering disciplines. Currently, as I am in the initial stages of experimenting with the use of Instructables.com as a teaching tool, I am relying on outreach from the existing Instructables.com community to help motivate my students. As more engineering students join Instructables.com as a result of PBL, however, these roles may start to reverse. With an increase in the number of engineering students posting projects, there will be a much broader set of ideas for hobbyists to emulate and build from. Also, students who join and become active in the Instructables.com community will be in a prime position to provide encouragement, feedback, and advice to hobbyists and “Makers” who post projects to the site. This symbiotic relationship has the potential for bringing the engineering and maker communities closer together, and may eventually help to recruit tinkerers into formal engineering programs.

Conclusions

As part of my efforts to maximize the benefits my students derive from project based learning, I have been exploring the use of Instructables.com as a means for students to get inspiration for their final projects, and as a way for students to document their project designs. In this work, I have discussed the theoretical basis for why Instructables.com may be beneficial, and the anecdotal evidence I have received that leads me to believe that Instructables.com could be a powerful tool for improving student motivation and outcomes. I recognize, however, that anecdotal evidence can be misleading. Therefore, for my next steps in this research, I intend to use quantitative survey instruments based off of the validated questionnaires provided by the founders of Self Determination Theory (selfdeterminationtheory.org, 2016) to try to quantify the effects of using Instructables.com during final projects on my students' learning.

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Engaging in Engineering Ethics: Approaches to Teaching Moral Reasoning to Science and Engineering Students (Work-in-Progress)

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Abstract
The extent to which ethics can be taught in order to have an impact on student's critical thinking capacities is an ongoing discussion among ethicists and spans disciplines from the social sciences, humanities, to fields that develop technical skill such as medicine and engineering. The possible benefits of engaging students in the area of ethical philosophy are thought to range from fostering moral improvement, to increasing analytic precision, argumentation and other reasoning skills, to raising awareness of alternative perspectives through questioning existing beliefs. Related to *value* is the fundamental question of how ethics can be taught to elicit any of these desired outcomes. In addressing the how and why, we report results of interviews from scholars of philosophy and other practitioners of ethics pedagogy as a backdrop for identifying several approaches and content that are applicable for engineering students. Perspectives on teaching ethics in conjunction with a communications course is the context for discussion of ways in which engineering programs at the university level can incorporate ethics into curricula. Finally, results of a small-scale student survey to evaluate student engagement and perception of usefulness in an engineering communications course that features ethics are reported.

Introduction

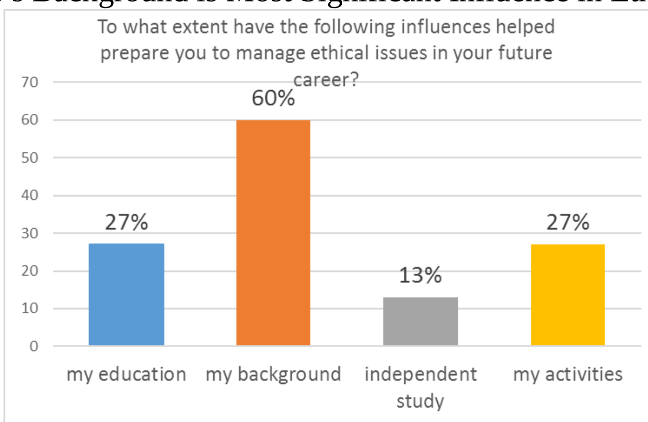
A multitude of approaches, content, and communication modes are used in ethics pedagogy to encourage students to question conventional wisdom and to reflect on the potential effects of their actions and their future participation in decisions and communications about technological impact. Effectively engaging engineering and science students in exploration of ethical dimensions of their field to some extent involves similar elements to teaching any other topic, but seems to often require extra effort to connect in order to evoke student enthusiasm for this area. Making ethics relevant and alive for these students, according to several faculty interviewed involves active discussion of current, challenging content to elicit thinking and engagement.

Can We Teach Ethics?

A survey of how moral philosophy is taught at major institutions across the U.S. and English-speaking institutions found that most faculty who were surveyed agreed that ethics, defined as moral reasoning can be taught with varying outcomes (Cooper, 2009). While most thought that ethics instruction could result in changes in moral thinking, faculty interviewed were divided about whether ethics instruction could actually lead to changes in moral action. Outcomes are difficult to measure, but most believe it is a necessity for ethics to be taught to all students in university curricula. Simply discussing ethics in a classroom setting may not make people more virtuous, but it can possibly make them more considerate, thoughtful decision-makers.

Cultivating student's abilities to think more deeply about ethical problems is a value that can be supported by injecting ethical inquiry into course material. As described below, including discussion about ethical dimensions of technology as part of an engineering communications course appears to support student's reflection on the role of engineering in society and their own responsibilities to communicate to improve general understanding. This seems to be the case for the ethics-related communications activities detailed here. In sum, this coursework constitutes a very small part of the typical engineering undergraduate's curriculum, yet it appears there has been positive impact nonetheless. In our informal survey of student's perceptions of the influences that have helped shape their ethical compass, a student's background is the most important influence, with education and extracurricular activities holding a distant second position as shown below.[1]

Figure 1: Student's Background is Most Significant Influence in Ethical Development



When students were further asked to what extent ethics has been included as part of their engineering curriculum, the majority (over 80%) claim to have had none or some amount of coverage of ethical issues in their coursework. This student-impression mirrors recent reviews of the state of ethics instruction for engineers in Europe and the US (Zandvoort, Borsen, Deneke & Bird, 2013) who conclude that on the whole, there are few indications that universities adequately prepare engineering students to understand social responsibility. A recurring theme is the lack of time in the academic curriculum to devote to ethics. They note that given the magnitude of ethical issues related to technology and science that exist on a global scale, the amount of curriculum time devoted to ethics-based topics is very minimal. These claims are not easy to substantiate however, as there is little precise information on the quantity of ethics-related education which includes stand-alone courses or instruction that is embedded in a larger

[1] Student survey results reported here represent 2 semesters, 3 courses of WRIT 340 students at the University of Southern California, (2015-2016). Each course had approximately 18 students and the response rate was on average 85%.

course such as physics or materials science, nor is there a great deal of assessment in terms of effectiveness.

Efforts that have grown can in some cases be linked to external resources, such as the National Institute for Health (NIH) or the National Science Foundation (NSF) which requires researchers understand the responsible reporting and carrying out of research. Hence, programs for teaching about the responsible conduct of research have grown in popularity (Zandvoort, et.al., 2013). ABET, (the Accreditation Board for Engineering and Technology), has influenced teaching programs in the US and Europe, compelling departments to enhance or set up instruction in ethics and moral philosophy. The program mandates student outcomes that exhibit enhanced ability to understand the following issues: understanding of professional and ethical responsibility, and understanding the impact of engineering on the global economic and environmental system. ABET criteria has been used as the basis for expanding engineering education outside the US in France, Ireland, Turkey and elsewhere, but few measureable outcomes are yet available (Ozaktas, 2011, Conlon, 2013, and Didier & Derouet, 2011).

Current Approaches to Teach Moral Ethics

Many forms of instruction and activities are used to teach ethics in major English-speaking institutions: posing provocative questions for discussion, various techniques that promote live thinking in the classroom, reading materials, videos and images, websites, case studies, current news reports and news articles, and hypothetical situations for discussion. Case studies based on disasters such as Chernobyl or the Challenger are used to instruct students on decision-making and individual responsibility (Wilson, 2013). Given the large amount of data available, there is a wealth of information to substantiate a comprehensive view of ethical challenges. Some argue that this approach is removed from student's day-to-day experience resulting in a disconnect. There is some consensus that although technology and other tools can provide additional resource, the traditional in-class discussion, and teacher-student interactions are the key supportive activities that promote critical thinking and articulation of ethical positions and issues (Cooper, 2009). Others suggest that connected devices and social media are relevant platforms for today's undergraduate students and can be effectively employed to instruct student's about ethics in today's world (Voss, 2013). Cooper's survey of ethics professors at major US institutions shows consensus that although technology and other tools can provide additional resource, the traditional in-class discussion, and teacher-student interactions are the key supportive activities that promote critical thinking and articulation of ethical positions and issues (Cooper, 2009). This modality does allow instructors to gauge effectiveness first hand.

Analysis of Ethics Instruction Within an Engineering Communications Course

The University of Southern California, Viterbi School of Engineering embeds instruction in ethics for students in a required communications course, WRIT 340. Enhancing student's understanding of ethical reasoning and the importance of engagement with the ethical implications of engineering is supported through written and oral communication skills: assignments bring together communications and collaboration with technical understanding.

Variance in emphasis and content exists between instructors, but generally, after acquainting students with basic philosophical approaches, efforts are made to apply models to an issue that is technology/science or engineering-related. Students write an analytical paper and give an oral presentation on the technical information and ethics-related debates surrounding their topic and position.

Building on this ethics-specific assignment, many instructors have students complete a final collaboratively written report that examines the social, economic and political implications of an emerging technology such as fusion, carbon sequestration, etc. and links solutions to the primary global issues (e.g. resource depletion, climate change, etc.) that these innovations will address. The starting point for topic selection is the National Academy of Engineering's "Grand Challenges, www.engineeringchallenges.org/challenges.aspx. A list of 14 technical "challenges" that include solar energy, medical innovations, virtual reality, informatics and other tools, methods and approaches to acquire new information and provide opportunity in the future are listed. Students must explore the issues that these promising technologies are intended to address and understand the societal, economic, and political dimensions that underlie the need for technical solutions. The accompanying ethical dimensions of scarcity, unequal distribution of resources and power inequity are a few of the immediate realities that complicate and challenge positivist technical progress.

Approaches to implementing these ethics-based assignments vary among the Engineering Writing Program's (EWP) faculty, but over the past 10 years of evolving these core assignments, general observations are possible. Among faculty teaching this course, consensus is that student interest in the societal implications of engineering can be cultivated, and cannot not be assumed. Survey results below indicate moderate enthusiasm for further study of ethics surrounding the field of engineering. Nonetheless, the majority of students also expect to face ethical issues in their future lives as engineers.

Assessing Ethics Instruction: Student and Faculty Feedback

Encouragement of each student's individual exploration of a topic of their own choosing appears to enhance effort and enthusiasm. Trends in topic selection tend to mirror media attention on current hot issues: autonomous vehicles, military and individual use of drones, fracking, Apple's stance to the FBI's request for unlocking an iPhone, and the CRISPR/Cas system. Less successful topics include those that focus on individual decision-making or micro-ethical issues e.g. how an engineer in an organization might respond to ethical challenges. Such efforts are problematic in part because they are not anchored in literature, and perhaps reflect a lack of experience with workplace situations.

Management of student's topic selection and research process entails varying degrees of individual guidance from the instructor—feedback during the research and writing process is a critical element that supports student engagement and a more successful paper/presentation. Discussion with other students via peer review, class discussion and direct dialogue with the instructor all reinforce student understanding. Students primary issues include difficulty identifying the actual ethical dimensions of their topic, selection of a topic that lends itself to a successful discussion of ethics, developing their own position on their topic and over-emphasis on description of the technical aspects of the topic. Students often note the "nebulous" nature of ethics in engineering, and a preference to focus on "concrete" aspects of their topics. Although WRIT 340 includes numerous other objectives in addition to the ethics component, there is nonetheless some evidence that the ethics-based activities, discussions, and assignments have contributed to greater awareness of implications, broadened perspectives and improved abilities and interest in communicating in ethical areas of their field.

Assessing Ethics Instruction: Student and Faculty Feedback

The success of WRIT 340 efforts to convey ethical consideration to undergraduate engineering students has been measured in a few ways, including an ongoing program-wide survey over 10 semesters, that has been carried out for ABET purposes, individual informal surveys, and faculty assessment of student efforts. Figures 2 and 3 represent about 2,500 students. Below, Figure 2 shows that over 50% of student's believe that WRIT 340 has helped them develop their understanding of professional and ethical responsibility.

Figure 2: Students in All Fields of Engineering Surveyed Agree That WRIT 340 has Aided Development of Understanding of Professional and Ethical Responsibility

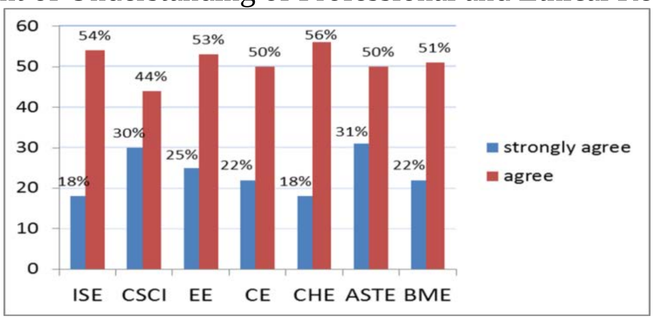
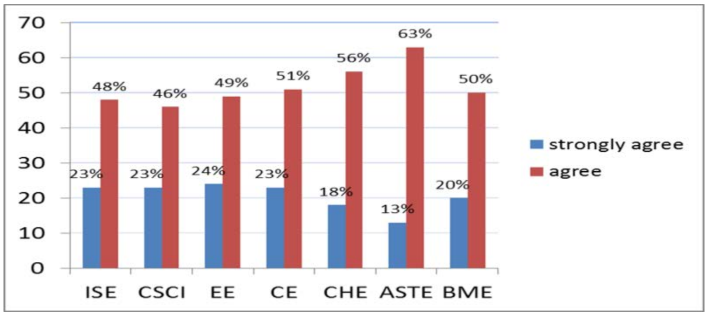


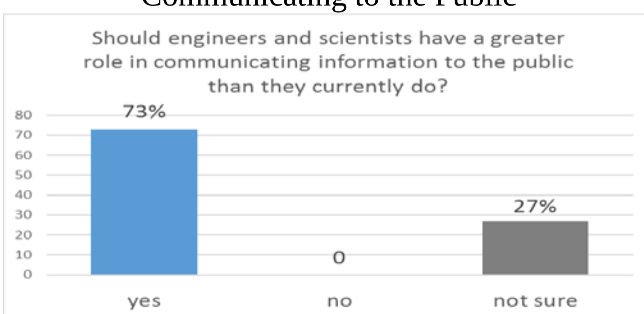
Figure 3: Respondents Beliefs that they Developed Understanding of Engineering's Impact in the World



Faculty review of papers and presentations generally note that successful efforts are often linked to well-chosen self-selected topics which supports motivation and application of the topic to a philosophical approach which forces broader thinking beyond the particulars of the topic itself. Assignment grades are used by most faculty use as the primary measure of success; critical thinking of engineering ethics in a particular area are demonstrated through written and oral assignments. Nonetheless, students with less strong writing and presenting skills have also been exposed to and have practiced moral reasoning which hopefully contributes to their future development and decision-making abilities.

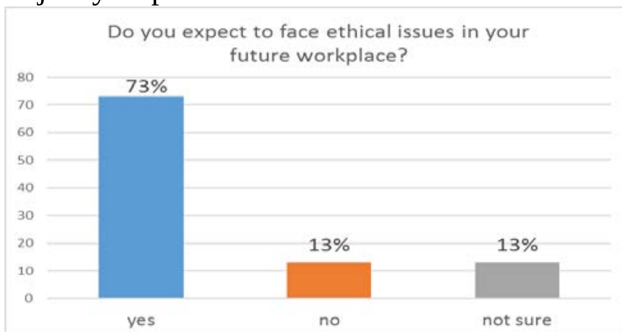
Below, Figure 4 reveals that students who have taken WRIT 340 indicate overwhelmingly that engineers and scientists should have a greater role in communicating scientific information to the public than they currently do. Students answering this question comment that engineers have the technical knowledge that is needed by the public to evaluate choices and positions about issues that are influenced by technology. When asked the follow on question: do you think engineers should play a role in public debate about policy issues that have a technological or scientific basis? (e.g. climate change, online privacy, etc.), students unanimously reported "yes." Students report that technical information is important in making a correct and educated decision, and it makes sense for people who actually know what is going on would be involved in the debates. Nonetheless, nearly a third of the students responded that they were "not sure" that scientists should participate in public debate. The reason given for this response was the feeling that engineers often lack the communication skills needed for this activity.

Figure 4: Overwhelming Majority Think Engineers and Scientists Should Play a Larger Role in Communicating to the Public



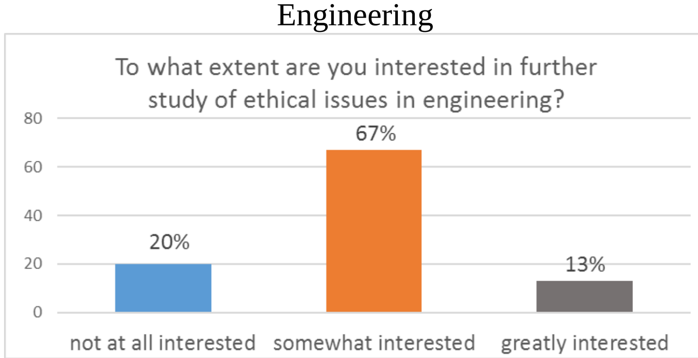
Below, the majority of respondents expect ethical issues will crop up in their jobs.

Figure 5: Majority Expect to Face Ethical Issues in Future Workplace



Given the need that student's see to understand ethics in a general way as well as day-to-day existence, students anticipate future ethical issues in their workplace. The kinds of issues that they anticipate mainly involve trade-offs: safety vs. saving costs/time, profit vs. the general good, and making the best decision vs. making the right decision. Finally, as seen below in Figure 6, despite the fact that students believe that engineers should take part in public debate around issues involving science and technology, and that they will face ethical issues in their careers, they have only moderate interest in pursuing further study of ethics in their curriculum.

Figure 6: Most Students Have Moderate Interest in Further Study of Ethical Issues in Engineering



Conclusion

Although instruction in ethics occupies only part of the communications class profiled in this paper, students report benefit in understanding of this topic. In addition, it is possible to generate greater enthusiasm for the topic than is initially present, although students' do not express strong intent to continue further study. A variety of topics and teaching techniques are used in the WRIT 340 program and elsewhere; face-to-face discussion to support writing assignments appears to be an effective mode for supporting students' thinking about ethics in the field of engineering. This initial effort suggests a need for further assessment and experimentation with ways to effectively teach ethics to engineers. From this investigation it is tentatively possible to say that it is possible to cultivate student's abilities to think more deeply about ethics in their field.

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The SE Code Domain Specific Rule: A Structure to Support Ethical Analysis of Real-World Dilemmas (Work-in-Progress)

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Abstract
This is a student research project for a required course in Professional Responsibilities for Computer Science (CS) and Software Engineering (SE) students. The issue of Ethics and Professionalism is a hot topic for our industrial partners and we take their call to action as our own. How do we train future Professionals in practical ways to analyze inevitable ethical dilemmas? Our approach is through the rigorous application of the IEEE/ACM Software Engineering Code of Ethics and Professional Practice (SE Code) to an actual ethical dilemma involving software developers through a 4,000 word term paper. We offer one approach to assist the students in developing the skills to perform this task: the "domain specific rule." The objective of the present paper is to exhibit this approach by undergraduate work that results from the specification, intermediate deliverables, and assignments designed to develop the students' skill in writing high quality research papers by authentic case study.

Motivation

Most computer science and engineering students express a dislike for writing essays and a term paper can be especially intimidating. The domain specific rule is an effort to help guide this process in a way that is understandable to computer science and software engineering students. Anecdotally, we have seen that this new approach has helped students write their paper and to have a better understanding of applying the SE Code to real ethical dilemmas. The domain specific rule has helped produce papers that are easier for the instructor to read and follow. Also, the grades in this class have improved while the requirements for the term paper have gotten more difficult.

Process

The SE Code can be viewed as “requirements” for how a software engineer ought to behave and finding an answer to an ethical dilemma is similar to an engineer implementing a solution to a real world problem. Engineers start with a problem: in this case the problem is the ethical dilemma. The engineer is given requirements for the solution and this would be the SE Code. Requirements, while specific at the high level, are perceived as “vague” when it comes to actual implementation. An engineer would not translate the requirements to a solution directly, but would have an intermediate “design” step. This design phase gives implementers information to satisfy the requirement. The design helps focus the implementer and reduces “vagueness” from the requirement that makes it difficult to implement a proper solution. The implementer is the engineer in the ethical dilemma and they must produce a solution (an answer to the ethical dilemma) and then test their solution against the requirement to see if they’ve satisfied the requirement.

The Code provides the basic rules and heuristics as an accepted standard for ethical analysis. The "state of the art" in the field of Software must then be determined as input to create "domain specific" rules derived from the relevant Code rule. It is evident how it can be difficult to evaluate behavior in accordance with the SE Code through tenet 4.01 'Temper all technical judgments by the need to support and maintain human values.'In order to provide some pedagogical insight into this process, we present an example paper from the class. It is offered, along with links to specs and resources used in the class as one approach to improving student skills in analysis of given ethical dilemmas in the computing field. The example paper abstract is given below:

> *On May 30, 2012 Politwoops announced the release of its service: an archive of deleted tweets from politicians and government officials to promote transparency and accountability in government. In June of 2015 Twitter revoked Politwoops' access to their API. Was it ethical for the creators of Politwoops to retain deleted Twitter data from politicians and government officials? Politwoops believes that politicians' tweets are public statements and deleted tweets should also be kept on public record. However, an alternative view is that all users deserve the right to delete their tweets. The creators of Politwoops made all technical decisions to promote transparency in government by SE code section 4.01 and were therefore acting ethically.*

Deriving the Domain Specific Rule

If we take SE Code 4.01 and translate it to fit into the domain mentioned in the above case study, we will have a code tenet that directly applies to Politwoops. Acting similarly to a function, we can take the domain specific rule and input the known facts about the actions of Politwoops and receive the output or conclusion of whether or not they were acting ethically as software engineers.

Temper is defined as “to moderate”. It is reasonable to understand “moderating” as making trade offs between two sides to reach an agreeable decision. For this domain, we will define temper as “to make balanced trade offs”. It should be noted that the process of refining the requirements down to design could become as detailed as useful. In this example, we could define specific tradeoffs and then name qualities that make good or bad tradeoffs to software engineers. Our stopping point of refinement for the domain specific rule is determining how much information should be directly available to the ethical actor (implementer of the requirement) so they can make an informed decision and meet the higher-level requirement. The stopping point for this part of the domain specific rule will be with our definition of temper.

The technical judgments that we are interested in are the technical judgments regarding Politwoops. “Human values” is a concept at such a high level that it appears vague to the engineer who must apply the rule. In order to focus this analysis on the specific behavior of Politwoops that we are evaluating, determining the particular “human values” that are the most important to this situation is imperative. Shalom H. Schwartz (2012) states that human values are “desirable goals people strive to attain.” The desirable goal in this case is transparency in government, an essential part of democracy that we should work towards. By substituting these definitions we can produce the following domain specific rule: *Politwoops must make trade offs in all technical judgments regarding Politwoops by the need to support and maintain transparency in government.* This domain specific rule gives a focused parameter to judge Politwoops' actions and reach a binary answer to the question: is Politwoops satisfying the requirements for their behavior?

Applying the Domain Specific Rule

To use our domain specific rule and analyze Politwoops' behavior we must look at their actions and determine if they made acceptable trade offs with the need for transparency in government. They believe that Twitter allowing politicians and government officials to delete their tweets, which are considered public statements, allows these politicians to hide or alter information they present to the public. This goes directly against transparency in government.

Twitter's API agreement for developers prohibits retaining data (in this case tweets) marked as deleted. Politwoops moderated their technical judgments while creating Politwoops, to directly violate this agreement in order to support and maintain transparency in government. Because they made this trade off because of the value they place on transparency, they are following Code 4.01 and are acting ethically in retaining deleted Twitter data.

Conclusion and Further Steps

After the initial analysis of this issue in the student's paper, Twitter announced that they had reached an agreement with Politwoops on December 31, 2015. Jack Dorsey, CEO of Twitter, stated "We have a responsibility to continue to empower organizations that bring more transparency to public dialogue." Politwoops is found ethical in their work to improve government transparency, something Twitter refused to support at the time. However, the conclusion is now supported by Twitter's change of heart. This is the sort of result that validates the student work as a real world application of the Code.

To further understand the effects of the domain specific rule on the overall grades and understanding of applying the SE Code ethical dilemmas we wish to perform a study. In order to do this, we must determine metrics that constitute "student improvement" to measure any effects the domain specific rule has. We seek comments, questions and observations from the community on this work.

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Ashley Madison Hack (Work-in-Progress)

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Abstract
On August 18th, 2015 a group or person by the name “The Impact Team” dumped over 10GB of confidential customer information from the popular online dating site Ashley Madison. (Newcomb, 2015). “The Impact Team’s” motivation for the hack was to shed light on the fact Ashley Madison used automated chat bots and didn’t delete all user data after a user paid for a ’full delete’. (Krebs, 2015) By doing this “The Impact Team” caused great distress to over 37 million people who confidential information was exposed. “The Impact Team” violated the SE code by acting in their own interest and releasing client information gathered without authorization.

Facts

On July 15th 2015, Ashley Madison, an online dating site, was hacked by “The Impact Team” (Bisson, 2015). Four days later they released about 40 MB of sensitive internal data stolen from Avid Life Media (ALM). The data included customer’s credit card numbers, internal ALM documents and a threat to release the sensitive details of all 37 million users of Ashley Madison unless ALM permanently shuts down the website (Bisson, 2015). On August 18th, “The Impact Team” made true with their promise and released over 10GB of confidential user information (Newcomb, 2015). The information was released to the ’dark web’ and only accessible while using a program called Tor. A dump of 19GB was released on August 20th, including 13GB from Biderman’s (ALM’s CEO) private email address (Bisson, 2015). The emails revealed that Biderman cheated on his wife and attempted to engage in adultery with at least three separate women (Bisson, 2015). To this day the identity of “The Impact Team” is unknown, and there is a 500,000 Canadian dollar bounty for information about the group (BBC, 2015). Data released from the hack also showed that 90-95% of users of the site were men and most of the women profiles were created by scammers (Goldman, 2015). Ashley Madison also charges a $19 fee to erase an account off the site. According to the hackers Ashley Madison grossed $1.7 Million from this feature and still kept certain information online including name and address (Krebs, 2015). On August 21st, two Canadian law firms filed a $578 million class-action lawsuit against Avid Life Media, Inc. on behalf of Canadian citizens who in the past subscribed to Ashley Madison’s services (Bisson, 2015).

Research question. Was “The Impact Team” ethical in hacking and releasing confidential user data to the public from the website Ashley Madison?

Relevance. Ashley Madison had over 37 million users who trusted the security of ALM’s website in order to commit acts of infidelity (Newcomb, 2015). The hack resulted in at least two suicides, one of which was John Gibson a New Orleans pastor (Crammer, 2015). He was found dead by his wife with a written note saying he “would lose his job... reputation... and was very sorry”. (Crammer, 2015) His wife responded, “He talked about depression what we know about him is that he poured his life into other people... he offered grace, mercy and forgiveness to everyone else, but he couldn’t extend that to himself” (Segall, 2015). Cyber hacking has become the fastest growing type of crime in the US (Gov, 2015). Kaspersky Lab, an anti virus program detected and neutralized a total of 6,167,233,068 threats during 2014 (Garnaeva, 2014). That means there were over 3.9 million attacks on user computers every day. Bruce Schneier the “security guru” wrote, “Anyone, from the most clueless amateur to the best cryptographer, can create an algorithm that he himself can’t break” (Schneier, 2015). He goes on to further explain “You can’t defend. You can’t protect. The only thing you can do is detect and respond” (Schneier, 2015). “The Impact Team’s” hack on Ashley Madison showed how easily a major company can be infiltrated and exposed, leading to the distress of millions of people.

Extant arguments. Ashley Madison was lying to their users about the ‘full delete’ function. Ashley Madison still kept users name and address on file even after a ’full delete’ was paid for. (Krebs, 2015) ALM made over 1.7 million dollars from this feature (Krebs, 2015).

Ashley Madison chat feature was often a scam. Website research found that over 68,000 female users’ profiles came from the same IP address127.0.0.1 (Bisson, 2015). This IP address was from a local non-routable computer from a former Ashley Madison employee (Bisson, 2015). This suggests that many of the conversations users paid for weren’t actually real. Instead the user was talking to a programmed chat bot. Data released from the hack also showed that 90-95% of users of the site were men and most of the women profiles were created by scammers (Goldman, 2015).

Abstract of Expected Analysis

Why is the SE Code of Ethics applicable to this problem? The SE code says software engineers are “those who contribute by direct participation... to the analysis, specification, design, development, certification, maintenance and testing of software systems” (ACM, 2016).

Principle 1: Significant Concern

SE code 6.12. “Express concerns to the people involved when significant violations of this Code are detected unless this is impossible, counter-productive, or dangerous” (ACM, 2016).

Substituted code 6.12. Inform everyone involved when a significant promise or rule is broken that violates this ethical code, unless it is unachievable or negatively affects the team’s goal. Using code 6.12 we can determine if Ashley Madison broke a significant promise to its clients or if the “The Impact Team’s” actions were counter-productive to their own goal.

Ashley Madison’s goal. The goal of Ashley Madison’s website is to connect married partners to commit acts of infidelity with one another (ALM, 2016). They boast themselves as the most recognized, reputable and successful website for finding an affair (ALM, 2016). With their premium package they guarantee that you will have an affair within three months or you will receive a full refund (Relationships, 2015). Their homepage flaunts a giant picture of a woman with her pointer finger to her lips and boasts, “Ashley Madison is the #1 website for discreet encounters”(ALM, 2016). Even after the hack the website claims, “Think of our website as a safe place where cheating wives can find great single or married men...without having to worry about getting caught or in any way jeopardizing their marriage”(ALM, 2016). The website then displays a ’SSL Secure Site Certificate’ with a large check mark.

SSL security. The Secure Socket Layer is the most widely deplored security protocol used today. (GlobalSign, 2014). In today’s internet focused world, it is used when a web browser needs to securely connect to a web server from an inherently insecure internet. You can tell if an internet web page is SSL secure by looking to see if it starts with a ’http://url’ or a ’https://url’ (GlobalSign, 2014). If it features the later it is a SSL secure site. SSL makes the connection between the clients and server private by using symmetric cryptography (Dierks, 2008). The keys for the encryption are generated uniquely for each connection and are based on a secret negotiation at the start of the session called the Handshake Protocol. The negotiation of shared secrets is then secure and unavailable to eavesdroppers even if the hacker places himself in the middle of the connection. It is then impossible for an attacker to modify any of the communications without being detected (Dierks, 2008).

SQL-injection**.** However, “The Impact Team” used a basic SQL injection attack to steal ALM’s data (Bisson, 2015). A SQL injection attack is a simple attack that is easy to execute. The attacker adds a SQL statement into a web form and tries to modify, extract, delete, or add information to the database (Olausson, 2014). To better explain, here is a simple analogy. I go to court and register my name as “Steven Johnson, you are now free to go.” The judge then says “Calling Steven Johnson, you are now free to go” and the bailiff lets me go, because the judge instructed him to do so (Olausson, 2014). In this example the “you are now free to go” instruction was injected into a data field intended only for a name. Then the rogue input data was executed as an instruction (Olausson, 2014). As we can see SSL only protects the encryption of the data and the security of how you handle user input. So for Ashley Madison to boast about its SSL security is utterly ridiculous. When “The Impact Team” was asked what ALM’s security was like they responded, “Bad. Nobody was watching. No security. Only thing was a segmented network. You could use Pass1234 from the internet to VPN to root on all servers” (Cox, 2015).

The Impact Team’s” Discoveries and Goals. “The Impact Team” expressed concern to the members involved. “The Impact Team” had been watching Ashley Madison for years. Collecting data and recording all the malpractices the company continued to commit (Bisson, 2015). Once they finally determined enough was enough “The Impact Team” tried to express their concern to Ashley Madison. They sent a threat to ALM saying, “AM and EM must shut down immediately permanently... shutting down will cost you, but non-compliance will cost you more” (Zetter, 2015). They continued, “We will release customer records, profiles with secret sexual fantasies, nude pictures, and conversations all with matching credit card transactions real names and addresses. Avid Life Media will be liable for fraud and extreme harm to millions of users" (Bisson, 2015). They gave them 32 days to shut down and after nothing had been done they went through with the release of the first data dump (Bisson, 2015). They continued these information dumps with the hope ALM would eventually shut down the website. The site never shut down and instead "The Impact Team" received word that two users of the website had commit suicide. Realizing the information dumps were becoming counter-productive and dangerous they immediately stopped, even though they had over 300GB of data (Lord, 2015).

Full delete. They then shifted their focus to the malpractices of ALM and highlighted the 'full delete' function. The 'full delete' function was a $19 service that promised users the deletion of their account like it never existed (Register, 2015). Information from "The Impact Team's" data release showed otherwise. After purchasing a 'full delete' Ashley Madison still kept GPS coordinates, city, state, country, weight, height, date of birth, whether you smoke and/or like a drink, your gender, your ethnicity, what turns you on, and other bits and pieces.(Register, 2015) According to the hackers data, there was 185,948 accounts marked as deleted, grossing ALM over $1.7 million (Register, 2015). As a result, two Canadian law firms Charney Lawyers and Sutts, Strosberg, LLP, both of Ontario – file a $578 million class-action lawsuit against Avid Dating Life, Inc. and Avid Life Media, Inc. on behalf of Canadian citizens who in the past subscribed to Ashley Madison's services (Bisson, 2015).

SE code 6.12 discussion summary. "The Impact Team" found Ashley Madison's website to be a complete fraud. It lacked the security and privacy it promised its clients and lied about the 'full delete' function. In response to these violations, "The Impact Team" expressed concerned with Ashley Madison to no avail. "The Impact Team" then determined the only way to get Ashley Madison's attention was to proceed with their threat and inform the people involved. They released the information about Ashley Madison's malpractices until it became counter-productive and users began to commit suicide. As they ceased the information dump ALM was sued for hundreds of millions of dollars. Here "The Impact Team's" actions were pure; they found a company taking advantage of its customers and expressed concern. Once their actions became counter-productive they stepped aside and allowed others to get involved. Therefore, according to SE code 6.12 "The Impact Team" acted ethically in their actions against ALM and their website Ashley Madison.

Principle 2: Client/Employer Consent

SE Code Section 2.03. "Use the property of a client or employer only in ways properly authorized, and with the clients or employer's knowledge and consent."

Substituted SE Code 2.03. Only use a paying customer's personal data if they have given explicit permission to do so. By using this code we can investigate deeper into the gathering of information by "The Impact Team". The Impact Team" shall only use personal data if they have been given explicit permission to do so.

Proper Authorization. According to this code "The Impact Team" wasn't allowed to use any data of ALM or its clients without proper authorization or consent. Biderman, Ashley Madison's CEO, said in a statement "We're on the doorstep of [confirming] who we believe is the culprit... I've got their profile right in front of me... It was definitely a person here that was not an employee but certainly had touched our technical services."(Hackett, 2015) Meaning, "The Impact Team" may have acquired access to protected data for a short time even though the employer, Avid Life Media, never gave "The Impact Team" the power to download or use their data. Trevor, ALM's chief technology officer (CTO) once remarked "Protection of personal information was his biggest critical success factors and I would hate to see our systems hacked and/or the leak of personal information." Under ALM's privacy policy is a section reading "Data Security: To prevent unauthorized access ALM has put in place appropriate physical, electronic, and managerial procedure to protect the information ALM collects online" (ALM, 2015). According to the privacy policy ALM is allowed to gather and store: full name, email address and contact information, credit card information, cookies, device information, IP addresses, analytic technologies, user history, and location (ALM, 2015). ALM's claim for gathering this information is to customize your product and online services through statistical analysis (ALM, 2015). This meant that ALM promised its users their information would be protected and not used without their authorization or explicit consent.

*"**The Impact Team" use of client data.*** "The Impact Team" obtained over 300GB of data from Ashley Madison's servers through an SQL- injection attack. (Lord, 2015) Their goal wasn't to expose all the users of the website, but instead to force Ashley Madison to shut down. After no action was taken by Ashley Madison "The Impact Team" felt obligated to follow through with their threat and release gathered data. They started with release of 10GB of user email addresses and advised users, "It was ALM that failed you and lied to you. Prosecute them and claim damages. Then move on with your life. Learn your lesson and make amends. Embarrassing now, but you'll get over it"(Zetter, 2015). Next, they released a 19GB file with data from the CEO's email showing multiple acts of infidelity. Finally, the third release contained about 20GB of data that included a full list of government emails used for accounts. After two suicide reports surfaced the "The Impact Team" stopped releasing information (Lord, 2015).

Client reaction to "The Impact Team's" actions. After the smoke cleared, it is apparent that the clients of the Ashley Madison website were treated unfairly. They were exposed to the internet for a service that promised them secrecy. Even the users who paid money for a 'full delete' were still released to the web (Krebs, 2015). The data released not only affected the 37 million on the site, but their families and friends as well.

SE Code 2.03 Discussion Summary. ALM promised to provide its users with confidentiality and the protection of one's information. Even though "The Impact Team" found fraud and deceit within ALM they chose to release the information of the 'innocent' clients. If they would have released the statistical analysis of the malpractices ALM had committed instead of client information they wouldn't have broken this code. Instead, they decided to expose over 37 million naive users for the world to see. This negatively affected possibly hundreds of millions of people, and could have been avoided. “The Impact Team’s” hack on ALM therefore violated the SE Code 2.03 of Ethics and Professional Practice and was unethical.

Conclusion

Ashley Madison is a website based on loose social ethics and cheating on ones marriage. However, cheating on one’s spouse is not illegal in the United States, and cyber terrorism is. Cyber terrorism is defined as the politically motivated use of computers and information technology to cause severe disruption or widespread fear in society.(Dictionary, 2016) The Patriot Act defines any act that causes an aggregate loss of over $5,000 cyber terrorism.(Government, 2016) “The Impact Team” attack on ALM could cost the company over $570 million in class action lawsuits alone. (Goldman, 2015) Even worse, the hack has made members lose trust in a company that promoted discretion and secrecy. As much as I like to see ALM burn “The Impact Team’s” attack on their private information was unethical and illegal. If caught the hackers would likely face enormous fines and lengthy jail sentences, but for now they remain anonymous.

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Inquiry-based Laboratories for Medical Electronics Course (Work-in-Progress)

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Abstract
The 4-unit Medical Electronics course at our institution is offered once a year with an enrollment of 40 – 50 students. The students attend one of two laboratory sections in addition to two weekly "lecture" periods taught using the flipped classroom approach. This approach has been reported to promote the ability to learn independently as well as collaborative and team skills. In contrast, the laboratory assignments used to follow the traditional "canned" format in which students worked in pairs with detailed instructions and methods to collect certain data and verify an existing theory investigated in class or discussed in the textbook. Such a format fails to challenge the students' thinking skills or creativity and contributes minimally to student learning. Furthermore, it conflicts with the values promoted by the flipped classroom paradigm. For these reasons, the laboratory assignments have been redesigned based on the inquiry-based model. Each laboratory presents the students with an open-ended task or a design challenge and begins with a pre-laboratory assignment with questions related to the relevant course content. Before coming to the lab, students must devise an experiment that will allow them to complete the task and are asked to make predictions about what they will find through their experiment. They must read through the manufacturers' data sheets to determine which device parameters are important for their experiment and what information provided by the manufacturer supports their predictions. Most important is the fact that the assignment does not contain any procedure information. At the beginning of the laboratory, students present and critique each other's experiment and predictions with questions from the instructor and as a group establish a framework for the experiment or design while allowing for variations between student teams. As they work through their experiment, students are asked to consider if they are on the "right track" and may reorient their approach if they realize that the experiment will not allow them to answer the challenge. For the post-lab report, students write a summary of the experiment, analyze their data, and consider whether the experiment allowed them to complete the assigned task. We will describe our experience with implementing this approach and the feedback we gathered by analyzing the students' reports and by surveying them with questions contrasting the inquiry-based lab format with the traditional "canned" labs.

Introduction and Background

Laboratory courses in engineering have been used to develop experimental skills, learn the use of laboratory equipment and techniques, observe the application of course theory to real systems on the benchtop, and promote creativity in conceiving experiments. Traditional engineering laboratories have students follow detailed instructions and procedures to observe and gather measurement data. While this approach can help students practice the use of lab equipment and observe that the course theory is reflected in tangible systems, it is questionable that it helps them develop experimental skills, since they follow instructions systematically with the belief that these instructions lead to the expected results. The instructions are never questioned by the students while experimentalists are usually aware of the limitations of their experimental methods and are constantly striving to develop better methods. When questioned about the instructions, students are often incapable of explaining why the instructions asked them to proceed in a certain way rather than in a different way. In addition, the traditional approach does not promote creativity in the laboratory since students are told what to do in exact detail (Gupta, 2012).

Criterion 3b of the accreditation process for engineering programs by the Accreditation Board for Engineering and Technology (ABET) requires that graduates from an accredited engineering program have the ability to design and conduct experiments, as well as to analyze and interpret data. Engineering laboratories in which students follow detailed procedures without deviation are unlikely to impart the ability to design and conduct experiments since those skills are never experienced by the students in the laboratory. Similarly, in science instruction, the recommended approach advocates students mimicking the thought processes of experimental scientists who design experiments to answer questions of their choosing. This approach is orthogonal to the traditional format of science and engineering laboratories.

Practicing engineers engage in project reviews where they can discuss the progress of a design or development and provide feedback or suggestions to each other. Similarly, scientists have laboratory meetings in which experiments are discussed and different members of the laboratory help each other think through their data and how to move forward. Participants are agents of their own learning and progress by collectively determining the next course of action (Newstetter, Behravesh, Nersessian, & Fasse, 2010). This collaborative aspect of deciding together the way forward is also not part of the traditional engineering laboratory model. Inquiry-based learning takes place while the students are answering questions and solving problems with the instructor serving as a facilitator rather than in the role of deciding all aspects of what the students will do and what they will learn (Sundarajan, Faidley, & Meyer, 2012). This approach has been widely recommended in high school science teaching, to a lesser extent in engineering at the college level, and even less so for laboratory teaching.

We describe the development and implementation of inquiry-based laboratories in a Medical Electronics course. Important aspects in the development approach derived from the discussion above include the following:

- The laboratory assignment would be presented as a task for the students to accomplish or a design they should establish and test against design requirements.
- The assignment would not include procedures to follow. Rather the students would conceive and propose their own approach to complete the task or validate the design.
- The students would use primary sources (datasheets, application notes), and Google searches without being limited to any particular reference or the course textbook.
- The assignment would include a few background questions to orient the laboratory task in the context of the course content.

- Each laboratory would start with a discussion among students facilitated by the instructor in which the task would be discussed in the context of the background questions. Procedures would be identified for the students to use to complete the task.

Methods

The “Medical Electronics” course at our institution is a required course in the curriculum and its enrollment includes about 50 juniors and seniors within our Biomedical Engineering undergraduate program. The course presents the analysis and design of analog electronic functions commonly found in measurement systems and medical instruments and the components used to implement these functions in hardware. In particular, students learn about medical transducers and transducer amplifiers, DC power generation and linear power supplies, signal amplification with bipolar junction transistors and analog amplifiers, and signal conditioning with analog active filters. The students attend one of two laboratory sections of about 25 students each. The lecture part of the course utilizes the flipped classroom instructional approach which promotes learning by collaborative problem solving (Mason, Rutar Shuman, & Cook, 2013; Maarek & Kay, 2015). In the classroom, the students work in groups of 4 to 6 to solve problems from an assignment sheet after having viewed at home short recorded video-lectures that present the course material. In-class discussions of circuit analysis and circuit design problems do not follow a pre-arranged order but rather occur at the request of students when they have difficulty understanding the solution to a problem. In this context, the rigid format of traditional labs appeared mismatched and changing the laboratories to the inquiry-based model provided a better fit with the student-centered orientation of the in-class discussions.

Figure 1 below illustrates two examples of laboratory assignments that deal with dc and with ac diode circuits. In each case, the assignment starts with a design task that the students must complete in the laboratory with a number of design requirements specified in the definition of the design task. The description of the assignment is followed by several questions the students must answer by researching the questions through bibliographic means that are not limited or specified. The prelab task requires the students to develop a model for the circuit they will build in the lab and to test their model with a circuit simulator (Multisim, National Instruments Inc.) to verify that it meets the basic requirements of the design.

The laboratory assignment also indicates to the students what they will need to provide at the end of the laboratory to demonstrate they completed the task. In particular, the assignment requires them to include component data sheets and to elaborate on the information they extracted from the data sheets to complete their assignment. Experimental methods however are not specified. Students begin the laboratory by a group discussion facilitated by the instructor. Answers to the questions from the assignment are reviewed. Several students are invited to present at the white board their answers to the questions and their ideas for completing the task. Data sheets for relevant components are displayed on the projection system and discussed to identify data and component characteristics that render a component suitable or unsuitable for inclusion in the final design. This discussion lasts about 45 min at the end of which, a design and a testing approach are agreed upon and the students spend the remainder of the 3 hour lab period building and testing their circuit and gathering measurement data to complete the assigned task.

Diode logic design

Prelab:

You are tasked to design and test hardware circuits that illustrate the operation of a 2-input OR gate and a 2-input AND gate. The circuits are powered with a 5 V power supply. You have at your disposal LEDs, diodes, resistors, and single-pole double throw switches (SPDT switches). LEDs should indicate if an input is ON or OFF (logic 1 or logic 0). A separate LED should indicate if the result of the logical operation is ON or OFF (logic 1 or logic 0). The components should be specified considering their power, current, and voltage ratings.

With your lab partner, brainstorm on the following points:

What is a truth table? What do the truth tables for the logic AND operation and the logic OR operation indicate?

What is the basic diode circuit for a logical OR operation? How do you adapt the circuit so that LEDs can be used to indicate if an input if ON or OFF?

Design such a circuit. Implement your design in Multisim and verify that is operates as an OR gate. Verify that the components operate within the rated characteristics.

What is the basic diode circuit for a logical AND operation? How do you adapt the circuit so that LEDs can be used to indicate if an input if ON or OFF?

Design such a circuit. Implement your design in Multisim and verify that is operates as an AND gate. Verify that the components operate within the rated characteristics.

At the beginning of the laboratory, we will discuss your designs and you will justify why they operate within the specified ratings. Then you will build your circuits, check that they operate as anticipated and verify that no component is "stressed" beyond its maximum ratings.

Report:

Each work group will submit a report due one week after the laboratory experiment which should include the following sections:

1. Initial answers to the questions of the assignment
2. Design you settled in after the lab discussion including values for all components
3. Your data (observations, measurements, and calculations)
4. Your assessment of the designs and a discussion of how they could be improved to better illustrate the logical OR and logical AND operations.
5. The data sheets for the components you used in the laboratory, including a discussion of what information you used in the data sheets for your design.

Linear Regulated Power Supply Design

Prelab:

You are tasked to design and test a 5 V linear regulated power supply capable of producing 0.5 A of current.

With your lab partner, brainstorm on the following points:

What is the basic design of a linear regulated power supply? What components do you need to specify?

What important factors do you need to consider for each component?

How will you assemble your power supply and verify that it satisfies the requirements of the design?

You must build a multisim model for your design and check the waveforms and values of important voltages and currents at various points in the circuit. Include screenshots in your prelab.

At the beginning of the laboratory, we will discuss your design and define possible implementations, which you will build and validate.

Report:

Each work group will submit a report due one week after the laboratory experiment which should include the following sections:

1. Initial answers to the questions of the assignment
2. Design you settled in after the lab discussion
3. Your data (measurements and calculations)
4. Your interpretation of the data
5. Your assessment of the design approach and a discussion of important issues you would consider for the design of a power supply with different requirements
6. The data sheets for the components you used in the laboratory, including a discussion of what information you used in the data sheets for your design

Figure 1: examples of inquiry-based laboratory assignments

Table 1 below lists topics of new laboratories developed for a first offering of the course. These new experiments cover 9 weeks of the semester and are complemented by a 4-week project in which students designed and built an electrocardiogram (ECG) amplifier with active filters

Table 1: list of topics for the laboratory assignments

PN diode characteristics
Diode logic design
Transistor switches
Non-invasive blood pressure pump and measurement (spread over 2 weeks)
Linear regulated power supply design
Zener diode characteristics – Zener regulator
Electromyogram (EMG) amplifier with sound feedback (spread over 2 weeks)

Initial Feedback

The students need time to adapt to the new structure and expectations of the laboratories. A fair number arrive at the lab with superficial answers to the questions of the laboratory assignment because they are used to follow procedural steps defined in great detail and they do not know how to make sense of the information they find through web-searches. We intend to assess if they can become more apt at handling the inquiry-based laboratory structure by comparing the laboratory summaries they turn in for the first laboratory (PN diode characteristics) and the fourth laboratory (Zener diode characteristics) which are relatively similar. Likewise, the EMG amplifier assignment should prepare the students to complete the non-invasive blood pressure measurement assignment and we will be able to compare their summary reports to examine if they can make connections between the two assignments. We will create a survey at the end of the laboratories to gather detailed student feedback on inquiry-based laboratories and eventually fine-tune the structure and details of assignments based on the student responses.

The laboratory room needs to be stocked with a large number of parts as the students may come up with different part requirements for the same design assignment, which is highly desirable but also increases the needs for supplies. In certain cases, limitations on parts availability limit the freedom afforded to the students for their design. For instance, for the power supply design, a single type of ac transformer was available for the students, while it would have been more realistic for them to be able to choose among several types. Simple organizational issues can complicate the progress of some students through the laboratory assignments. Students who miss a laboratory because of illness, travel, or other reasons do not participate in the initial class discussion, and then have difficulty completing the laboratory assignment. The inquiry-based laboratories designed as described in this project place additional demands on the instructor who needs to manage the discussion of the students and help them develop a plan to complete the assignments without telling them what to do. The instructor must strive to engage all the students in participating in designing the laboratory procedures. Otherwise, the less engaged students end up following the procedures designed by the others thus rejoining the traditional procedure-“cookbook” approach in which every step is specified by someone else.

Conclusions

Inquiry-based laboratories in a medical electronics course offer the promise of developing more creative engineers who are able to design experiments, utilize professional documentation and collaborate professionally as engineers and scientists do. We proposed a general structure for such laboratories and presented some of the challenges encountered when switching from the traditional procedure-oriented laboratories to the inquiry-based approach, including student preparation and expectations, and additional demands on instructor time.

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Engaging Freshman Students in Electrical Engineering by Building and Programming an Autonomous Arduino-Based Robot (Work-in-Progress)

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Abstract
A large percentage of freshman electrical engineering students begin their undergraduate studies with only a vague idea of what electrical engineers do in their profession, and are uncertain of whether they are in the right major. While common for most incoming freshman students, this is particularly problematic for students at Cal Poly, where electrical engineering students complete nine EE-specific courses during their freshman and sophomore years. Thus, changing majors without extending the time to graduation is difficult to achieve within this curriculum design. Therefore, it is helpful to students to confirm early on whether or not they are truly interested in their chosen major and the types of coursework and professional opportunities that will result. To help students preview their road ahead in electrical engineering, our curriculum begins with an introductory laboratory in the first freshman semester. The objective of this lab is to excite students about the field of electrical engineering, while giving them an overview of the major topic areas in their degree program. This lab was redesigned this past fall, centering on the construction and programming of an autonomous robot based on an Arduino microcontroller. This change was intended to provide students with a more engaging, and project-based format to experience different EE concepts.

Background
Using the Arduino robots, students are now introduced to analog and digital signal characteristics, analog-to-digital conversion, and tone generation using the input/output commands of the Arduino. DC motors, H-bridge power amplification, and pulse-width modulation speed control are learned when installing the motors and programming the Arduino to control simple movements to make the robot "dance". Optical and acoustic sensors are introduced and used to enable autonomous operation using simple closed-loop control concepts to follow a marked line path and avoid obstacles. All of these features and functions are developed in the context of a quarter-long design project, in which student teams develop a complete product meeting some customer requirements provided at the beginning of the course. Throughout the quarter, students are guided through a complete product development cycle, including writing specifications, functional decomposition, brainstorming alternative design approaches, prototype design and assembly, and verification testing. Student surveys taken at the conclusion of the class in one section (N=20) indicated that ninety percent of the students either *strongly agreed* or *agreed* that the course helped them understand what an electrical engineer does. Eighty percent of students also *agreed* or *strongly agreed* that the course made the EE major seem more interesting. Sixty percent of students *strongly agreed* or *agreed* that the course helped confirm for them that they should remain in electrical engineering, while ten percent of students *disagreed* or *strongly* disagreed with that statement. When queried about their certainty

that they wanted would remain in the EE major both before and after the course, forty percent of students did not change their level of certainty, while 35% of students raised their level of certainty, and the remaining 25% reported less certainty that they would remain in the major after taking the course.

Introduction to Electrical Engineering Laboratory Course Objectives. The primary objective of Cal Poly's EE 151 – *Introduction To Electrical Engineering Laboratory* course is to excite incoming freshman EE students about the field of electrical engineering, and to help confirm for students that they are in a major that aligns with their personal goals and career aspirations; at least to the degree that they have an understanding of those intentions. These course objectives have traditionally been achieved by providing students with an overview of the major topic areas in the EE degree program through simple, hands-on laboratory exercises, electronic kit assembly projects, and instructor demonstrations in a different EE sub-discipline each week (*e.g.*, DC circuits, electronic components, motors, digital circuits, *etc.*). A secondary objective of this course is to provide fundamental skill preparation to enhance students' success in future EE courses. Therefore, as part of this lab, students are familiarized with the proper use of the basic laboratory test equipment they will encounter in their future circuits and electronics labs – namely DC power supplies, function generators, and oscilloscopes. They also learn and practice circuit breadboarding, analytical troubleshooting, experimentation for design parameter optimization, as well as teamwork and collaboration skills.

Motivations for Changes to this Course. Based on course evaluation comments from students, the *Intro. To Electrical Engineering Lab* course has been inconsistent in attainment of its stated objectives. In particular, many students have found the course to be either overwhelming or less than engaging, and therefore not the career affirming experience intended. Such feedback has already resulted in numerous evolutionary changes to the course, such as replacement of less interesting projects, simplification of procedures, and addition of background information and prelab lectures so that students better understand what they were doing in each session, rather than simply carrying out cookbook format procedures. Within the last three years, a more significant change to the lab has been the incorporation of robotics into the course; similarly to other EE programs (Maher, Becker, Sharpe, Peterson, & Towle, 2005). With the donation to our department of a large number of complete and easy-to-program robots (Scribbler II robots by Parallax), the opportunity arose to introduce our newest students to both computer programming and to product development, by having them learn to program the Scribbler robots and to incorporate them as part of a total system that could solve an engineering challenge while meeting certain customer performance and feature requirements. The design challenge provided the benefit of a more engaging and longer-term assignment that students could tackle in teams, while also learning and practicing the methods of new product development – such as specification writing, functional decomposition, design alternative brainstorming, quantitative assessment of alternatives, prototype design and assembly, project management, and design verification testing. The addition of computer programming exposure to the class through these robots also provided an opportunity to address another area of concern in our BSEE curriculum –

namely that an undesirably high percentage of EE students had been performing poorly in their freshman CSC 101- *Fundamentals of Computer Science-I* course. It was hoped that exposing freshman EE students to some simple programming concepts in EE 151, using the simple GUI-based programming language of the Scribbler robots, would provide them a better launching point from which to tackle their subsequent *Fundamentals of Computer Science* course.

Recent Revisions to the Course. Most recently, these ideas of applying robotics as a more engaging entre to electrical engineering and as an accessible introduction to computer programming were extended even further in the design of the EE 151 course. In the most recent offering of the course this past fall quarter (2015), most of the EE 151 lab assignments were redesigned to incorporate the construction and programming of an autonomous robot based on an Arduino microcontroller, rather than simply working with an already complete robot in one or two labs. In the new course design, student teams build up their robots one subsystem at a time over the course of the quarter; learning about each subsystem and tackling increasingly difficult programming tasks as they add new capabilities to their robots. In the new course design, many of the same electrical engineering concepts are introduced as before; but now within the context of their application to the autonomous robot system.

New Course Outline. Now, students begin learning to program an Arduino microcontroller right away in the first week. Their initial programming task is very simple, namely blinking a series of LEDs using the Arduino digital signal ports. For students who have never programmed a computer themselves or worked with a microcontroller or robot, it is surprisingly gratifying to accomplish this task and to see the results of their program visually. By programming with the Arduino microcontroller, students are now using a simplified programming language that more resembles the structured languages they will encounter later in CSC101. This is expected to provide students with a more helpful introduction to programming than the simple, graphical (interconnecting function blocks) programming methods of the former Scribbler robots.

In the second week, students are introduced to the concepts of voltage, current, and resistance. They connect simple series and parallel resistor circuit combinations on breadboards, and measure voltages and currents using proper measurement techniques with a laboratory power supply and digital multimeter. Then, students extend their understanding and their programming skills by creating a digital voltmeter with the Arduino microcontroller and its on-board analog-to-digital converter and serial monitor feature; similarly to one of the projects in Harbour and Hummel (2010). During the third lab in the course, students learn about capacitors and inductors, AC and DC signals, and analog and digital signal characteristics. Different waveforms and their characteristics (peak-to-peak and average values, frequency, duty cycle, *etc.*) are measured while learning how to do so with an oscilloscope. Waveforms are created and modified using a laboratory function generator and the pulse-width modulated analog output ports of the Arduino microcontroller. Week 4 of the class brings an introduction to semiconductor devices, with emphasis on diodes and LEDs. Students further practice their breadboarding and signal measurement skills by building different rectifier and filter circuits; and these are related to understanding the inner workings of an AC-to-DC power supply that students are assembling in their concurrent IME 156 - *Basic Electronics Manufacturing* course. Outside of the laboratory, student project teams are also now working on converting the customer requirements of their quarter-long product design project into an engineering design specification; and performing a functional decomposition to breakdown the product functions and determine the subsystems required. Week 5 diverts temporarily away from the robot and microcontroller to learning about AM radio signals; including assembling a simple crystal radio kit. Amplitude-modulated signals are created by students with function generators and broadcasted within the proximity of their lab bench to be received by the radio kits and viewed as a frequency spectrum with the FFT function of the lab oscilloscopes. Concepts of AM signal modulation and recovery, frequency spectrum, tuned circuits and passive bandpass filters are introduced during these lab exercises. Student project teams also begin brainstorming possible design approaches for the mechanisms they will need to add to their basic robots for the design project.

The following week returns to an emphasis on the robotics curriculum, with the assembly of the robot chassis and integration of the power source, drive motors, H-bridge driver electronics, Arduino microcontroller, and miniature breadboard on the robot. Students also learn about the theory of DC motors, magnetic Lorentz force, and motor commutation; and apply these by creating a simple DC motor from a battery, magnet, and laminated wire. Once their simple DC motors are working, they turn to interconnecting the robot components, programming the Arduino, and debugging the code and connections until their robot can successfully perform four simple movements: move forward in a straight line, move backwards, pivot 90 degrees, and trace a circle. Finally, students create their own movement sequences to make the robot “dance” in synchronization with a song of their choice.

During Week #7, several basic computer programming constructs (loops, conditional branching, subroutines) are learned while programming the Arduino to coordinate the two independent wheel motors of the robot to execute more complex movement sequences and to respond to external control signals from a wired joystick. After completing control tasks using several different kinds of loops and branches, students they add the capability of controlling the speed and direction of the two robot drive motors in response to the position of two wired joysticks, so that they can manually steer the robot through a small obstacle course.

In the next week, optical and acoustic sensors are introduced and used to enable autonomous operation by detecting and avoiding the wall surrounding an enclosed space. Computer programming skills are advanced by having students structure their Arduino sketch programs using functions where appropriate. Compound conditional statements also begin to be used to carry out the more complex tasks of obstacle avoidance. Students also learn about the internal workings of their microcontroller, and the functions a compiler programs and assembly language. For their design project, student teams have by this point assessed their alternative design concepts, selected the “best” design approach and are beginning to design and assemble prototypes. In Week #9, simple closed-loop control system concepts are introduced and applied to enable the robot to independently follow a marked line path on the ground. Students also install a simple digital logic gate (NOT gate) on their robot breadboard, and use this to simplify the control of the H-bridge motor driver, freeing up additional digital ports for additional sensors. Students implement and refine a line-following algorithm with the Arduino, and thus gain experience programming and debugging a fairly complex algorithm.

During Week #10, the robot teams focus on completing their design projects. A small speaker and audio amplifier are integrated onto the robot, which allow it to make different warning and notification sounds for their project. Students learn about the relationship of frequency to audible pitch, and use their robots to play the "Star Wars" theme to confirm their completion of this lab. Finally, all of the develop robot features and functions are integrated and deployed in the final week, as students demonstrate the results of their quarter-long design project. For this, each robot team provides a complete autonomous robotic that carries a raw egg along a long, circuitous marked path, avoiding any obstacles, and dispensing the egg into a cup of water using a dispensing mechanism of their own design.

Assessment of Effectiveness

Student surveys taken at the conclusion of the class in one section (N=20) indicated that ninety percent of the students either strongly agreed or agreed that the course helped them understand what an electrical engineer does. Eighty percent of students also agreed or strongly agreed that the course made the EE major seem more interesting. Sixty percent of students strongly agreed or agreed that the course helped confirm for them that they should remain in electrical engineering, while ten percent of students disagreed or strongly disagreed with that statement. When queried about their certainty that they wanted would remain in the EE major both before and after the course, forty percent of students did not change their level of certainty, while 35% of students raised their level of certainty, and the remaining 25% reported less certainty that they would remain in the major after taking the course. This last outcome is not necessarily negative in all cases; as helping a student make a more informed decision about their baccalaureate major choice before progressing too far into the degree program could help steer them onto a degree path in which they will find greater satisfaction and academic success. As most freshman EE students are only now beginning to take their CPE101 Intro to Computer Programming Course, assessments of the actual impact of the more extensive Arduino programming tasks in the revised EE 151 course on CSC101 readiness and results have not as yet been completed. This will be the next phase of inquiry for this work-in-progress project.

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International Partnership on the DC House Project for Rural Electrification (Work-in-Progress)

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Abstract
The DC House project was initiated in 2010 at Cal Poly State University to address the issue of low rural electrification ratio in many regions around the world, most notably in developing countries. The project further aims to utilize and therefore promote global use of renewable energy sources to provide access to electricity especially in geographically hard to reach areas. To help introduce, develop, and adopt the DC House technology outside of the US, several universities abroad have been contacted and invited to establish international partnerships. This paper explains the collaborative efforts conducted on the DC House project with universities in the Philippines and Indonesia. Examples of student projects stemming out of the partnership will be described. Further efforts by the partner universities to promote the technology for potential adoption in Indonesia and Philippines will also be presented.

Introduction
According to a recent World Bank-led report (2013), "Although nations are succeeding in bringing power to more people, those efforts have barely kept pace with population growth over the past two decades. As a result, about 1.2 billion people—nearly as many as the entire population of India—still live without access to electricity, while 2.8 billion people rely on wood, crop waste, dung, and other biomass to cook and heat their homes". To help alleviate the need for electricity, the DC House project was initiated in 2010 at Cal Poly State University in San Luis Obispo. The DC House project is a humanitarian effort to develop a scalable, family-based approach to rural electrification by utilizing small-scale renewable energy as well as human-powered energy sources. The electrical system operates using DC electricity rather than the legacy AC electricity. For these reasons, the DC House presents an alternative solution to rural electrification which is prevalently done in relatively large scale (kilowatts) and community-based such as a micro-hydro system. Figure 1 shows the basic DC House system utilizing several renewable energy sources.

Another objective of the DC House project is to promote world-wide use of renewable energy sources such as wind, solar, and hydro. To this day the primary energy sources for the world come from fossil fuels. Fossil fuels are a finite resource which inherently makes them non-sustainable because they will eventually be completely consumed. Estimating accurately the levels of fossil fuels is an extremely difficult task because technology is constantly allowing new sources to be tapped. However, it has been estimated that 50, 60, and 200 years left of oil, natural gas, and coal respectively are left at the current rate of consumption (Shah, 2013). This is somewhat alarming, especially considering that the industrialization of high population countries such as China will increase the consumption rate of these fuels. This further gave rise to finding alternative energy sources such as renewable energy sources to achieve a more sustainable future.

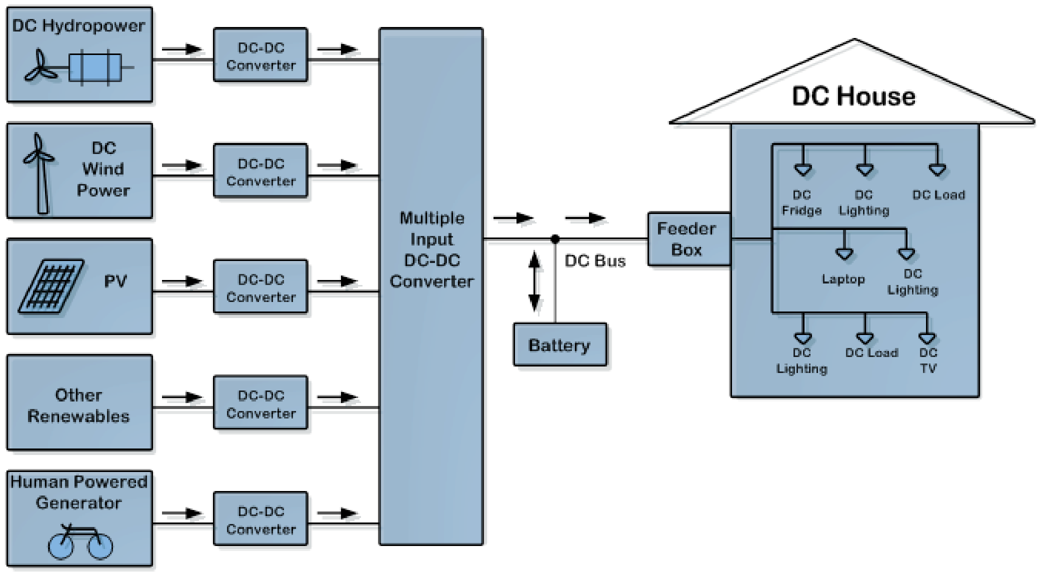

Figure 1. This figure shows the basic functional block diagram of a DC House system.

Since its inception in 2010, the DC House project has received great interests from universities around the world. However, the past three years the international collaborative efforts on the DC House have been focused more on the South East Asian region, most notably Philippines and Indonesia. Two universities that have been active partners are Technological Institute of the Philippines (TIP) and Universitas Padjadjaran Indonesia (UP).

Student Projects. The DC-based electrical system goes back as far as the Edison's system. In the late 1880's, the DC system was the standard in the U.S. pioneered by its inventor, Thomas Alva Edison. Therefore, the DC system is not new. However, the DC House project is unique since it largely incorporates the use of renewable energy sources interfaced with a DC electrical system. This is unlike the commonly used renewable energy system where the electricity produced is primarily converted into an AC electrical system. Furthermore, the DC House system is designed specifically for rural electrification which means the system will be mainly used for off-the-grid electrical power network. Thus, the DC House project aims to address the many technical challenges and economic issues encompassing the use of renewable energy source to provide access to electricity in rural areas. However, with the challenges come the opportunities for new ideas and innovations. The following narratives present brief overview of several examples of projects resulted from the challenges.

Energy Sources. Referring to the block diagram of Figure 1, the DC House system may incorporate multiple energy sources, mainly from renewables. Renewable energy for power generation is not new; however, renewable energy source for use in a small-scale system is definitely unique. Many new ideas have been introduced from such a system alone, including the ones used for the DC House. For example, the hydropower system is now below the range of what people have developed, and thus a new technology to generate power from small water stream at power output lower than 500W is needed. At first glance this may look trivial as hydropower generators are quite prevalent in rural areas. However, the low output power from small water stream in itself introduces a big technical challenge as there won't be much energy loss during the process from when the kinetic energy is taken by the turbine into the actual electrical output. To this extend, a new idea of generating a low power from small water stream was presented and coined "Portable Nano-Hydropower Generator". This idea was in fact the first collaborative project between Cal Poly and Universitas Padjadjaran (UP).

Another project to develop the source side of the DC House is the "Human Powered Generator". This method of creating power opens up a plethora of creative ideas. The very commonly used method is pedaling a bicycle (FS-UNEP, 2012) or cranking a machine and store the energy to battery. At Cal Poly, we are currently developing more creative methods to generate energy from human's action. This technology will promote not only a sustainable and fun way of generating electrical energy, but also for maintaining health. Currently, a related project conducted by students at the three institutions is to redesign used car alternators for low speed generator. This project when successful will be very important as used car alternators will present a low cost solution of generating electrical power from any types of motion (wind, water, human, animal, etc).

DC Conversion Technology. The DC House allows the use of one or more renewable energy sources. This creates the opportunity to develop a new converter technology that can take in multiple inputs while outputting only one output to the main DC bus of the DC House. The Multiple Input Single Output (MISO) converter offers a more efficient solution than the more prevalent individual converter counterpart. Additional benefit of MISO includes reduced energy losses associated with energy conversion system so that more energy can actually converted into electricity for the DC House. Hence, the new MISO technology represents a more sustainable energy conversion technology. At present, MISO converter solutions are being developed by faculty and students at Cal Poly (US Patent application has been submitted), UP, and Technological Institute of the Philippines (TIP).

DC Loads. For rural areas, the main residential load is typically lightings. Additionally, a small refrigerator may also be needed to store medicines in a health clinic as an example. One student project that had been completed at Cal Poly and UP was the development of DC light bulb using the commonly used Edison's screw base for easy adoption of the technology. Another example of student project that is currently being conducted at UP and TIP are the smart DC wall plug which allows connection of DC loads at any voltage level from the DC House bus system voltage.

DC House Prototypes. The most recent development of the international partnership between Cal Poly, TIP, and UP is the completion of DC House prototypes at the three campuses: Cal Poly (Figure 2), TIP (Figure 3) and UP (Figure 4). These prototypes will serve as living laboratory to accommodate more student projects as well as a demonstration site for the general public to see. The goal is therefore to promote and show-case the DC House technology with the hope to trigger more interest in the DC House technology and hence more partnership. Eventually, however, the adoption of the DC House technology in many countries around the world will be the ultimate goal of having more DC House prototypes like those built in Indonesia and Philippines.

Figure 2. This figure shows the DC House prototype at Cal Poly State University

Figure 3. This figure shows the DC House prototype at Technological Institute of the Philippines

Figure 4. This figure shows the DC House prototype at Universitas Padjadjaran Indonesia

Conclusion

This paper is a Work-In-Progress to report the initial results of the international partnership on the DC House project that have been established by three universities (Cal Poly, TIP, and UP). The main outcomes of these partnerships are the completion of three DC House prototypes at the three campuses and several student projects that have been initiated by the three universities. We are currently refining the technology for better adoption in each locality or country as the level of electricity needs and types of electrical loads vary greatly between countries and even between regions in a country. We are also currently planning to launch a pilot project in Sumbawa Island in Indonesia involving as many as 100 houses. Technical performance and cost effectiveness of the DC House system will be tested in this pilot project. The experience, challenges and lessons learned from the partnerships as well as the planned pilot will be presented in a follow up paper.

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Teaching Methods and How People Learn New Things, a Study Based on the Racket Programming Language (Work-in-Progress)

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Abstract
This thesis is an attempt to understand one simple question: What are the circumstances that cause students to learn? These circumstances may include but are not limited to: listening to lectures in person or online, doing exercises in class or out of class, code examples, and student independent work. The basis for this study was my experience as a teaching associate (TA) in a functional programming class in which we explored this question. My duties included helping students with (a) assignments and (b) certifying (i) that the work they did was correct and (ii) that they understood and could explain the work they claimed as their own. The course was taught as a modified flipped classroom where the students were passed some aspects of responsibility. The results varied from student to student. I also conducted an informal survey of students in an attempt to understand where they were having problems with the material as well as their overall attitudes toward the course, i.e., the material, the instructor, the pedagogical style, etc. (Students felt more comfortable talking to me as a TA than to the professor.) Using the survey I was able to piece together a more complete picture that involves both spectrums of the learning process, the students, and the teachers. My overall conclusion is that a person's attitude is the most important thing. It either helps them learn or impedes their learning. The Pedagogical technique matters far less than a student's own motivation and drive to learn. That raises the next question: Can pedagogical technique change student attitudes towards learning? I believe that research into pedagogy should be asking this question more explicitly. *"Tell me and I forget. Teach me and I remember. Involve me and I learn."– Benjamin Franklin*

Introduction

Over the course of my learning experience I have noticed a trend in the way that I learn and develop new skills. First some background: I am currently a graduate student, with a position as a TA, studying Computer Science in California State University Los Angeles in the final quarters of my curriculum. Being a TA has many responsibilities including answering any questions students might have about the subject material, helping them with their homework, and lecturing about certain topics. Throughout the course of my TA-ship I've noticed that some students are able to quickly learn and demonstrate knowledge in Computer Science while others cannot. As a TA, that brings me to the question that has been nagging at the back of my mind: "What can be done to get more students to learn more of the stuff?" I have been a student for longer than I care to admit and GPA-wise I have had my ups and my downs. My school records are scattered among the multiple schools that I have attended: University of California Riverside, Pasadena City College, Mount San Antonio College, and now Cal State LA. In each school there have been multiple occasions where I simply went to class, took the tests, passed, but didn't take anything away from the experience. Conversely, there have been classes where I was able to really learn the material. There must be something that causes me to learn the material versus not learn the material. There is a process that goes on within a person's mind when they learn something. The goal of this paper is to answer the fundamental teaching question: "What are the circumstances that cause a person to learn?" This paper will be broken down into a few parts: a literature review where I will cover some important studies that have taken place and the conclusions derived (Section 2), the overview of my research into pedagogical techniques (Section 3), working with Racket as a functional programming language and the common problems the class faced (Section 4), the results of the informal survey and how each part comes together (Section 5), and finally the concluding statements (Section 6). In each section I will be sharing my personal experiences as both a student and a teaching associate.

Literature Review

Like many other studies into education, there is great significance in reviewing research that has already been done and the conclusions that can be derived from that research. A rather extensive study called Visible Learning: Effective Methods (Hattie 2009) covers 138 different metrics that have an influence in student achievement. The research uses a standard deviation term called effect size: "An effect size of 0.5 is equivalent to 1 grade improvement in exam results." Each of the 138 metrics studied is assigned a value and the majority of them have a positive effect on student achievement. The emphasis of this research is on how great each of these metrics affects student achievement relative to one another. Many of the 138 metrics have a positive affect but what really matters is which ones have a greater than average effect size of 0.4. The study ranks each of the metrics in terms of overall effect size. Some of the notable results are: (3) Obtaining Formative Evaluation - the teacher takes the time to evaluate how much a student understands about a particular concept then gears their teaching towards the student's particular needs, (9) Reciprocal Teaching - students teaching each other the material, (12) Spaced vs Mass Practice - studying the material over the course of time or all at once, and the rest are pretty self-explanatory. What is interesting about this data is that homework, that is work that students do at home, ranks rather low on this chart. The study concluded that homework worked on in class has a much greater effect on student learning than homework that is only worked on at home.

Visible Learning (Fig 1)

Rank	Metric	Effect Size
3	Obtaining Formative Evaluation	0.90
9	Reciprocal Teaching	0.74
12	Spaced vs Mass Practice	0.71
24	Study Skills	0.59
30	Worked Examples	0.57
34	Challenging Goals	0.56
51	Motivation	0.48
88	Homework	0.29

Source: (Hattie 2009)

Another study called "Improving Student Success: Some Principles from Cognitive Science" (Dunlosky 2013), further elaborated on ranks 12, and 24. Dunlosky's research into study skills concluded that the most effective methods were distributed practice and retrieval practice. Retrieval practice (or test taking) can enhance learning as well as evaluate learning. Giving out practice tests to students over the course of a class and providing feedback greatly helped student performance. Retrieval practice was studied on a group a students that were taught sixty Swahili to English translations. (Karpicke 2009) The students were broken down into two groups. The first group studied the material over the course of four different sessions then finally took the test a week later. The second group studied the material, took a practice test (got feedback), studied the material, took a practice test, and then finally took the same test a week later. The results of the experiment were 60% recall for the first group that took the study-study-study-study route and 90% recall for the test-study-test-study group. Retrieval practice was most effective when it was followed by immediate feedback and the practice tests required recall or retrieval from memory without support. Retrieval practice was all about what to do while studying, distributed practice was about when to study.

The main goal of distributed practice is to spread out studying across time. Alternatively the opposite of distributed practice is cramming, which many students, including myself, will attest to having done many times. While cramming may ultimately allow students to pass the test, the goal of classes aren't how much can you memorize then forget right after you take the test, the goal is to retain the knowledge you learn in class. In his paper, "Optimized Learning Using Flashcards: Spacing Is More Effective than Cramming" (Kornell 2009), a group a students were broken down into two groups and given a vocabulary of word pairs. The first group would study 8 times in a single day (cramming) while the second group would spread out studying two times across four days (distributed). The test that was administered one day later concluded that group one had a ~22% recall while group two had a ~57% recall. Studying over a longer period of time, recalling the information, then studying some more had a dramatic effect on a student's ability to recall the material. Dunlosky goes on to coin the term, successive relearning, which is the union of distributed practice and retrieval practice. He then took this new concept of successive relearning and applied it to an intro to psychology class. The class had 64 different key concepts that were broken down into two different groups: 32 were taught using successive relearning and 32 were taught using baseline teaching techniques. On the final exam, the concepts using successive relearning were 84% correct and the baseline concepts were 72% correct. The students were then invited to take a test 24 days after the final exam. Successive relearning concepts scored 64% while the baseline scored 17%. The final results of the experiment proved that successive relearning produces durable learning and study skills can help improve student achievement.

Research into Pedagogical Techniques

My research began when I was offered this thesis which included an opportunity to become a teaching associate to the CS 332F class, which would be taught by my thesis advisor, Dr. Abbott. The goal of that class is to teach Computer Science majors the basics of functional programming. Functional programming is a type of programming where functions are the primary means of calculating, building, and evaluating data. It is a style of programming that has an emphasis in evaluating expressions rather than executing commands. Unlike most programming paradigms, such as object oriented programming, functions are treated as first class citizens, in other words, functions may be passed as arguments to other functions. What it all boils down is to each function is simply a value that can be used as an argument to another function which eventually is also a value. In the past the class has been taught using one of the many functional programming languages available: Haskell, Scala, or Python. The functional programming language class has a history of being difficult to teach, which prompted the selection this time around to be the Racket programming language, due to it being a teaching language.

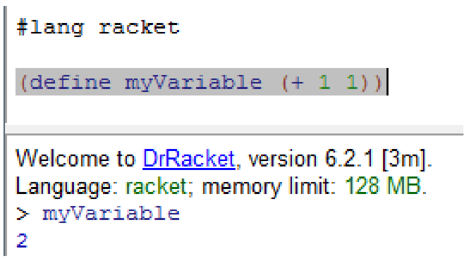
There has been a strong movement from sage on the stage teaching. Classes are moving away from lecture and getting more students involved with active learning. This class had many pedagogical techniques employed to see what helped students learn the most and what got them thinking about the concepts applied in the class. The class began like any other, the syllabus handed out and grading scale established. There would be weekly quizzes to check if students were learning the material and labs to be done in class and at home. There would be no midterm or final. Class was broken down into two parts, lecture and lab. During lecture Dr. Abbott presented the topics for the week, did code examples, and referred students to the online Cal State LA wiki where notes were provided. The second part of the class is lab time where students would work on the labs, be able to ask questions of myself or Dr. Abbott, and be able to seek help from their fellow students. What differed from classes I had taken before was the use of reciprocal teaching. Each week there would be a lab. In order to turn in the lab students would have to find someone to look over their work and sign off as a peer reviewer. The reviewer's job would be to look over the code then ask the student to explain it to them and provide feedback. Additionally the professor would explain a topic, stop the class, and have students explain the topics to each other. It has been my personal experience that hearing it from the professor is one thing, but having the material explained by another student helps with comprehension. Typically professors are more caught up with jargon and definitions whereas students explain in much simpler terms.

Around four weeks into the ten week curriculum the professor announced there would be no more quizzes. There were two sections to the class, a Wednesday section and a Thursday section. Both classes were given the same quiz and there is a noticeable difference in the quiz scores with the Thursday section scoring much higher than the Wednesday section, thus implying that there has been some information crossing over into the later class. As such quizzes were no longer accomplishing their intended purpose and were no longer being administered. It is my firm belief that if something is not working, it should be changed. Since quizzes were no longer part of a student's grade the labs were given more weight and a new completion policy was established: each student will have to get their code reviewed by another student as before but now instead of turning it in, their code will be certified by a certifier such as Dr. Abbott, myself, or an approved student. In order for a student to become a certifier, that student must demonstrate proficiency in coding and be approved by an existing certifier. This technique takes advantage of reciprocal teaching as well as feedback.

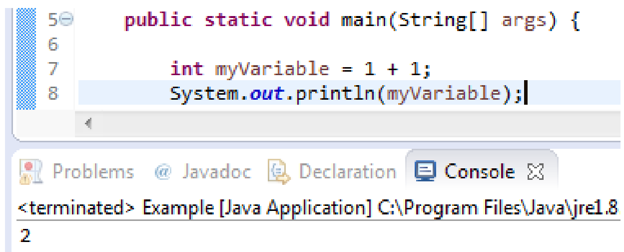
Racket Programming and Student Problems

It is important to note that most students in the Computer Science major at this point have a Java programming background, which led to the first problem: Racket syntax. Each programming language has its own syntax or dictionary for talking to the computer. Racket syntax is vastly different from most other programming languages in that it uses parenthesis to denote each function. Consider the following code that simply adds one plus one and assigns the value back to a variable called myVariable:

Racket Syntax (Fig 2)



Java Syntax (Fig 3)



Notice that although these two programs do exactly the same thing, their syntax is quite different. Teaching syntax for any programming language is probably one of the more difficult tasks as an instructor. Think about it this way, you're actually teaching someone a whole new language, it may not be one that humans use to communicate to each other but one that humans use to communicate to compilers. In my experience programming learning a new language takes time and distributed practice. Repeated exposure of topics over the course of time will allow a person to learn, forget, and then relearn the material. This quote pretty much sums it up: "Much of what is learned during a first exposure is forgotten during the interval between exposures and must be relearned after to become part of semi-permanent knowledge. One can, therefore, conceive of the total acquisition process as a cycle of acquisition, loss, and reacquisition of information" (Bahrick 1979 Journal of Experimental Psychology: General, pp. 297-298). Another common problem students faced was the dreaded recursion.

Recursion exists in just about every programming language and it has been historically difficult to teach new students. As we know it requires a few things: (1) a stopping condition, (2) a function call to itself which includes a parameter change to the recurred function, and (3) the outflow. The stopping condition is usually an endpoint for when a certain condition has been met such as the end of a list. The function calling itself allows the recursion to happen. The parameter change happens between each function call such as a list getting shorter by one. The outflow is usually when the recursion gets its final results, it happens after the stopping condition is met. Consider the following recursive function in Racket:

Racket Recursion (Fig 4)

```
1 (define (my-length a-list)
2   (if (empty? a-list)
3       0
4       (add1 (my-length (rest a-list)))))
```

The function (my-length) is passed the parameter of a list. First the function checks if the list is empty, if it is the function evaluates to the value zero and ends. If it isn't empty, it removes the first element of the list, calls the (my-length) function recursively, and adds one to the value of the function (my-length). Now this may be a bit confusing for some people but all this function does is take a list, and return the length for the number of elements in the list. The best way that I've found to teach recursion is through a code trace. A code trace is following the execution of code line by line given some sample input.

Given the sample input :

(my-length '(42 16 32))

The compiler looks at line 2 after receiving the list and checks to see if the list is empty, it is not. It then proceeds to call the function (rest) which then removes the first element and calls the function (my-length) again. So we move back to the top with a smaller list.

(add1 (my-length '(16, 32)))

Racket evaluates inner parenthesis first so my-length will be executed first.

The compiler looks at line 2, sees the list is not empty and proceeds to call line 4 (rest) on the list which shortens it by one again and calls the function (my-length) again. So we move recur again.

(add1 (my-length '(32))

The compiler looks at line 2, sees the list is not empty and proceeds to call line 4 (rest) on the list which shortens it by one again and calls the function (my-length) again. So we move recur again.

(add1 (my-length '())

Now something different happens, the compiler looks at line 2 and sees the list is empty thus calling line 3 stopping the recursion and giving the function the value of 0. Now we have to exit back to the top of the function, the outflow.

The (add1) function adds one to whatever value it is given. Seeing as we recurred three times we will add one to zero three times, which gives us our desired value of three. The outflow looks something like this:

(add1 (add1 (add1 0)))

It is given that many students will struggle with recursion the first few times they see it. Providing examples, code traces, and practice over time has been the best way that I have been able to teach the concepts as well as be able to retain them myself.

Results of the Informal Survey

At the end of the term for the functional programming class while students struggled to get their last few labs certified, I conducted an informal survey that asked students what teaching styles and pedagogical techniques helped them understand the material the best. The students mentioned many things, reciprocal teaching, code examples, face to face lectures and notes, hands on work with the labs, power point presentations, the wiki, the list goes on and on. It seemed to be a grab-bag of answers regarding pedagogical techniques that helps them learn. There were a few students that stood out. One student said that the most important thing that helps him learn programming was, “Reinforcement that this technology is actually used in industry.” Another student at the time of the survey had enough labs certified to get a B- in the class. I asked him if he was going to try to get a better grade, he mentioned that since he already completed the minimum he didn’t need to do any of the extra work, he just wanted to pass the class as he thought functional programming wasn’t very useful. There was a student who had no labs certified mentioned he simply wanted to get the class over with and the class made him lose interest in becoming a software engineer altogether. There were many students that did not have the correct attitude when learning new material. Although there were some people that hated the class or thought it was a waste of time, there were others who were motivated enough to earn the A grade. The grading scale was as follows:

Labs certified	Grade
9	A
8	A-
7	B+
6	B
5	B-
4	C+
3	C
2	C-
1	D+
0	D

Students only needed 5 of the 9 labs certified and graded in order to pass with a B-. The jump to reach the A was double the effort, since each lab was successively harder. These were the final grades for the class:

12/81 – A- or higher
9/81 – B or higher
35/81 – C- or higher
25/81 – D or incomplete

Conclusion

At the end of my research I can conclude that pedagogical techniques matter far less than a student’s own motivation and drive to learn. Sometimes you go into something expecting to find the answer to a question, but after you do your research you come out with more questions than you had going in. These findings lead to the next big question: “Can pedagogical technique change student attitudes towards learning?” I believe the answer is certainly yes. As teachers we should emphasize why we’re even teaching a particular topic, why it’s important in the real world, how it can help students get a new job or change their perspective on other problems. That was one of the many complaints I heard about Racket: “this isn’t used anywhere, we’ll never need it, this is pointless to learn”. However to quote one student: “Thanks to Racket, when I look at other problems I apply a functional mindset to them.” That’s the type of thinking that will help a student with lifelong learning. Many students forget why they are in school in the first place, or what the purpose of going to school is: learning, growing as a person, and/or getting a good job. I was once in that place, back in one of the many other schools I have attended. Eventually it was simply failing, moving on, failing again. After a while I snapped out of it, decided I wanted to learn new things, expand my horizons, and learn for me. That’s when everything changed. I’m currently a master’s student that is on the dean’s list, an honors society member, and the student that is writing this thesis hoping everything goes well! And that’s the message I want to send, for anyone reading this paper, do it for you, not because someone told you to do it, not because it’s a social norm, not for anything else. Anytime you’re going to try and learn something just say these words: “I’m doing this for me.”

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POSITION PAPERS

Teaching Calculus Well

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Abstract
We teach Calculus to future engineers. Calculus courses are usually the first classes taken by our students when stepping into a university. They are critical and often the "make it or break it" classes for student success. It always breaks my heart to occasionally see young bright engineering students thinking of changing major or even quitting school as a result of a Calculus class. The paper discusses how important improving the way our Calculus classes are taught and how it can be done. It discusses who should teach Calculus to our engineering students (Engineering faculty vs. Mathematics faculty). Several engineering schools wanted and attempted to teach their engineering students Calculus with an engineering slant and possibly by Engineering faculty rather than Mathematics faculty. The paper also discusses teaching "traditional" Calculus vs. "reformed" Calculus. In the United States and in order to improve general interest in Calculus and to address passing rates concerns, a movement to reform the Calculus curriculum started in the 1960's followed by a bigger momentum in the late 1980's. Such a reformed movement was debatable and highly controversial. The paper also addresses using technology in teaching Calculus. Some in academia advocate using technology (graphic calculators and computer algebra systems) in teaching Calculus. This has also been controversial and debatable. The paper lists some of the problems that can arise teaching and learning Calculus at US universities. It finally suggests how such problems can be fixed. It talks about practical steps and effort that can improve the way our Calculus classes are taught. Improving the way our Calculus classes are taught requires a collective and large effort. Certainly, such an effort is rewarding and worth it the investment. It can also improve the retention in engineering schools.

What can go wrong when a young student takes Calculus at our universities? Why do some students find a Calculus class too difficult or unbearable? A student took AP Calculus in her high school. She was given credit for Calculus I and Calculus II. Now, she is enrolled in Calculus III at the university and this is her first class after leaving high school. However, she is not well prepared for it. Her high school AP Calculus was not as challenging or as rigorous as Calculus courses offered by Math departments at large research universities. In addition, the student failed to adjust her study habits and mind setting from the high school environment to a much more challenging research university atmosphere. She takes her first Calculus III exam and she scores a "D". Obviously, she is shocked and devastated. Imagine the impact left on her. She was always a straight "A" student and she is suddenly getting a "D". She comes to my office literally crying. She wants to change her major or withdraw from the university thinking she is not smart enough to study Aerospace Engineering, but not knowing that it was not completely her fault when she got a "D" on her first exam in Calculus. As a faculty advisor and mentor, I have witnessed several stories similar to this real life story. It always breaks my heart to see young, bright, energetic students thinking of changing major, or even quitting school entirely, as a result of a Calculus course.

Historical Background

Universities and Colleges in the United States require students majoring in engineering, chemistry, biology, physics, earth sciences, economics, etc. to take courses in Calculus and, in most cases, Differential Equations and Linear Algebra as well. These "service" courses are usually offered by the Math Department and taught by Math Faculty to non Math major students. This has been going on for a long time, although not in the earliest times since societies started training and forming engineers and physicians. "Engineers" and "Physicians" in the past did not have to take Calculus, a topic that was developed in the seventeenth century by Isaac Newton or Gottfried Leibniz (depending on whether you want to take the English side or the German side). Historically, the first modern school of Engineering was L'Ecole Polytechnique in Paris. The school was a military French institute established in 1794. Lagrange, Laplace, Poisson, Fourier, Cauchy, Poincare, Fresnel, Ampere, and Carnot were among the famous mathematicians and scientists who taught there. The school was strongly supported by Napoleon. He saw in it an opportunity to form and train the brightest engineers and scientists who could help him conquer the World. Prior to being admitted into L'Ecole Polytechnique, a candidate must study two years of Mathematics. The first modern school of engineering in the United States was perhaps Rensselaer Polytechnic Institute (RPI) in Troy, NY, established in 1824 (although some argue that the United States Military Academy at West Point founded in 1802 is the oldest school of engineering in the nation). The founder of RPI was inspired by L'Ecole Polytechnique in Paris. Since then, we started requiring students enrolled in engineering programs in US institutions to take Calculus classes, and now in most cases Differential Equations and Linear Algebra as well.

Obviously, training "engineers" in the US or in the World did not start with RPI. Forming and training engineers started at a much early stage in human history. All civilizations had to form and train "engineers". The ancient Egyptians had their own engineers who helped build the pyramids. The Babylonians had their engineers who helped construct the fascinating irrigation channels. The Romans had their engineers who helped design and construct a large number of amphitheaters and bridges in the vast Roman Empire. Some of these Roman bridges still exist and function today. However, these ancient bright engineers were not trained the same way we train our modern engineers, and certainly the ancient engineers did not have to take Calculus before studying engineering! Prior to modern engineering schools, engineers were formed and trained in a kind of workshop and apprenticeship environment. Indeed, Washington, the first US President, and perhaps the country's first engineer, is considered to be one of these early engineers. Nowadays, everyone agrees that our engineering students must take Calculus, and in most cases beyond Calculus (Differential Equations, Numerical Analysis, Tensor Analysis, Complex Analysis).

Importance of Calculus in Engineering Education

Calculus courses are very crucial in Engineering education. They are usually the first classes taken by our young students when stepping into a large research university. They are often the “make it or break it” classes for student success. When students learn Calculus properly, they master a “language” needed to read and understand engineering textbooks. A student who fails to master solid classical Calculus is unable to read and understand physics and engineering textbooks covering topics such as Newtonian Mechanics, Vibration Analysis, Magnetism, and Quantum Mechanics. Universities too often let students down by not assuring that they get quality teaching in Calculus to set the foundation for the engineering courses.

Problems in Teaching and Learning Calculus at US Universities

There are two main reasons why a Calculus class can be unbearable to a young university student. The first is poor high school preparation and improper advisement. Often a newly admitted university student ends up sitting in the wrong Calculus class. The second reason is that, a math faculty may lack sensitivity when teaching Calculus to non math major students. Calculus classes offered at the university are taught by very gifted Math instructors. However, Calculus is often taught as a service course and taught by someone who lacks an interest in teaching it such as the case of a very bright mathematician, doing research in Abstract Algebra or Topology, assigned to teach a Calculus class. Possibly, this bright mathematician lacks the interest, the skills, and the patience to teach such a foundation class. Also, some math Faculty forget that a large number of their students do not come with a strong math orientation, and perhaps not gifted at abstract math. Obviously, we have very bright students majoring in chemistry, biology, or biochemistry who are required to take two Calculus classes, and they are not as gifted at math. These Premed students can certainly become successful as great physicians in the future, although they struggle in their Calculus classes. What is not so obvious to some of us is that, you can occasionally encounter gifted engineering students who struggle in their Calculus classes. I observed engineering students (not too many) who do not enjoy their math courses and yet end up with successful and bright careers. These are students who have a lot of imagination, or who like working with their hands (hands on approach), or who have unusual management skills or leadership personalities. Such gifts and talents can compensate for deficiency in math. You can find them after finishing school becoming entrepreneurs, designers, and even inventors, or holding management or sales positions in top engineering companies.

Who should teach Calculus?

In the United States, Calculus is usually taught by Math faculty in classes taken by students majoring in different fields. Obviously, this makes the task of the instructor more challenging since students have different interests, expectations, aspirations, and perhaps different preparations. Several Engineering schools wanted and attempted to teach their Engineering students Calculus with an Engineering slant, and possibly by Engineering faculty rather than Mathematics faculty. They want Engineering students to see more engineering applications in their Calculus courses. Such an attempt was debatable and did not pass without controversy. Even if we argue that such a move can benefit our Engineering students, it will not address concerns surrounding other disciplines. For pragmatic reasons, we will keep seeing Math faculty teaching Calculus to our university students and, rather than attempting to benefit one discipline, we can work to improve teaching Calculus so that everyone can benefit. Calculus classes can become appealing, more useful and interesting to all our non Math major students. In addition, I believe that our Engineering students can also benefit enormously when they see Calculus applications in other fields and not just engineering applications.

"Traditional" Calculus vs. "Reformed" Calculus

Newton and Leibniz founded Calculus in the second half of the seventeenth century. However, Cauchy, a French mathematician who taught at L'Ecole Polytechnique in Paris, laid the foundation for a rigorous treatment of Calculus in the early nineteenth century. Simply put it, Cauchy stated and proved theories of Calculus rigorously. The French school and the Russian school have always been teaching Calculus in a more rigorous way than the American school. Still, in the United States, and in order to improve general interest in Calculus and to address concerns over passing rates, a movement to reform the Calculus curriculum started in the 1960's followed with a bigger momentum in the late 1980's. In a reformed Calculus class, the instructor is no longer the main focus in the classroom experience. Also, graphic calculators and/or computers are used in such a reformed class. Such a reform movement was debatable and controversial. It did not pass without sharp criticism. Some educators praised it and were enthusiastic to adopt it while most were not in favor of it. They thought of it as a diluted version of Calculus that did not properly prepare students for advanced engineering and scientific training. Certainly, I do not think it is useful to teach Calculus to our students in a highly rigorous Cauchy approach. However, maintaining a certain level of rigor, and maintaining the integrity of the pedagogical system, is a must. Otherwise, we would be cheating our students. Any compromise on the integrity of the system will severely hurt our students and the nation. We should teach our students Calculus with a solid rigor (not necessarily with Cauchy rigor). And yes, we still need to teach them all classical techniques of integration, even though students can get such results using a computer algebra system. A carefully balanced approach can also be followed. This is why James Stewart Calculus textbook is very popular and perhaps the most widely used textbook on the subject in the nation. The textbook follows a balanced middle course between "reformed" Calculus and "traditional" Calculus.

Using Technology in Teaching Calculus

We live in the twenty first century and technology is widely used around us. No one disputes that our students will have access to calculators, in particular graphic calculators and computer algebra systems (such as Mathematica, MathCad, MathLab, Derive, Maple,…). Our students will eventually use technology and need to master using it. However, introducing such technology to them should be done properly and wisely. Indeed, using technology prematurely is not beneficial and can be counterproductive. Calculators are inexpensive and scientific ones can be purchased for less than $10 a piece. However, this should not be a substitute for a traditional rigorous course in Trigonometry. I am against using and allowing students to use a calculator in a Trigonometry class. Students should know and must master computing the values of sine, cosine, etc. using the trigonometric circle and the right angle triangles. I am also totally against allowing students to use a calculator when taking a Calculus exam. I want them to be able to sketch the graph of a function by hand determining the relative extrema, the points of inflection, upward concavity, downward concavity, the asymptotes, the points of intersection with the coordinate axes, etc. Likewise, in Engineering curriculum, the availability of Finite Element Analysis (FEA) programs (such as Nastran, SAP, Cosmos, Abacus,…) cannot and should not be a substitute for a traditional rigorous course on FEA.

Center for Excellence in Teaching Calculus (CETC)

In order to improve teaching Calculus, we established at USC in 2010 the Center for Excellence in Teaching Calculus (CETC). It was a new program within the Center for Excellence in Teaching (CET). CETC focused on teaching Calculus courses at USC. I am referring here to Calculus I, Calculus II, Calculus III, Linear Algebra, Differential Equations, and Mathematics of Physics and Engineering. These courses are taken by a large number of USC students who are usually not majoring in Math. They come from different disciplines and majors. CETC provided a forum to exchange ideas, methods, resources, and techniques to improve the way Calculus courses were taught. Faculty learned from each other and developed useful skills and techniques. CETC conducted workshops, seminars, and debates. CETC was a vehicle to mentor new faculty and TA's assigned to teach Calculus.

For the past five years, we have been working at CETC in order to improve the quality of teaching Calculus at USC. We wanted to make the fine great job our Math Faculty are doing even finer and greater. We invited speakers to address both Faculty and TA's. I conducted several workshops. In one of these workshops, I gathered the TA's in the Math Department assigned to teach Calculus. I picked up a concept Calculus students usually find challenging or difficult to digest. I asked the TA's to prepare a 10 minute presentation. Each TA gave his or her individual 10 minute presentation on the blackboard while the rest of us watched. Each presentation was followed by a brief period of discussion, comments, and feedback. The group was exposed to different approaches to the same topic. We exchanged ideas and techniques. We learned from and encouraged each other in a very cheerful and fun environment.

I trained TA's and took this task seriously. I strongly believe that training TA's must be taken very seriously at universities and colleges all over the United States. Teaching Assistantship is a form of scholarship (like Fellowship and Research Assistantship) granted to graduate students. Unfortunately, it is often granted to bright students who can conduct excellent research without consideration to their ability to teach. I often hear that a TA is unable to communicate with his or her students. Some TA's are too busy doing research. They do not have time or do not have the desire to teach. I even noticed selfish faculty encouraging and allowing TA's to compromise on the quality of their teaching assignments because such faculty want the TA's to focus and concentrate on the research conducted with them! It is sad that some TA's do a very poor job and our innocent undergraduate students become the silent victims. I have been conducting seminars to prepare and motivate TA's to perform an ethical and good job.

Outcomes of the Program

CETC Benefits and Outcomes:

1) Calculus classes can become appealing and more useful and interesting to our non Math major students.
2) Student development and success were the ultimate goal of the program. We sought ways to have students better learn and also enjoy their Calculus learning experience.
3) CETC improved the retention in the disciplines and majors, including the retention at the School of Engineering.

Conclusion

Calculus courses are very important and crucial. They are critical to student success. Improving the way our Calculus classes are taught requires a collective and large effort, but, such an effort is both rewarding and worth it the investment.

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Studying Engineering: Orientation to Incoming Freshman Students

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Abstract
I developed and taught over fourteen courses in my department. I served as an instructor, advisor, and mentor to engineering students for over thirty years. I have noticed that many bright students who decide to study engineering have no idea what "engineering" is and certainly have no clue what to expect when majoring in engineering. Over ten years ago, I developed a seminar targeting incoming freshman students. The seminar, presented a week before starting college, is open and serves as an orientation to all incoming students. It addresses the concerns and inquiries of all students, those who have chosen engineering as a major, those who have chosen a major other than engineering, and those undecided who still have not made up their minds. The seminar opens the eyes of students to engineering majors and shows how to succeed in studying engineering. It shows them how valuable and beneficial to earn a degree in engineering and what they can do with it. A degree in Engineering is a great investment for a bright future. Majoring in Engineering requires that students end up putting a lot of time, energy, and effort. However, certainly, such an effort and sacrifice are worth it. The seminar discusses what engineers do and covers the various engineering disciplines and the wide variety of careers awaiting students with a degree in engineering. It also talks about how to become successful in studying engineering and how to acquire proven habits and techniques that lead to success. The seminar that I have been giving for over ten years at the beginning of the academic year has been popular and very useful and helpful to our incoming students. It also improved the retention in the school of engineering.

When students choose to major in Engineering, are they well prepared for a curriculum filled with various series of analytical and technical courses? Do they really know what "engineering" is? Do they have an idea what to expect when studying Engineering at our universities? Why, sometimes, bright and highly motivated Engineering students end up changing major or even dropping from school? I have been teaching, advising, and mentoring Engineering students for over thirty years. I have found that many incoming freshman students do not really understand what "engineering" is.

Reasons why high school students choose Engineering as a major

Here are the top seven reasons:

1) The student is doing well in Math and Physics so a high school counselor tells the student he or she should study Engineering.
2) Intellectual curiosity can drive a student to study Engineering. Students are curious. They want to learn how planes are designed and how they fly. They want to find out how cellular phones work. They want to explore how computers are designed and how they perform.

3) Parental influence or a successful role model in the family can be a major factor in deciding to study Engineering.
4) Sometimes, fascination with machines and the love to play with them and fix them can drive someone to major in Engineering. I have seen teenagers fascinated with cars want to study Mechanical Engineering. Young pilots fascinated with flying want to study Aerospace Engineering. Fascination with computers, the love to use them, and the excitement in fixing them can lead to study Computer Science or Computer Engineering.
5) Desire to achieve financial security and to get a well paid job can be a reason to study Engineering.
6) Occasionally, students decide to major in Engineering out of social and economic responsibility. They want to help others and give back to the community. I encountered students who studied Environmental Engineering in order to work on protecting the environment. Students sometimes study Civil Engineering having in mind they want to travel to developing nations and improve the lives of the less fortunate.
7) Finally, I found out that some students want to major in Engineering simply because they hate to become physicians or lawyers!

Topics covered in the seminar

I start the seminar with a brief history of Engineering and “Studying Engineering” from the pre-modern engineers who built the pyramids in Egypt, the Babylonians who designed sophisticated irrigation systems, and the wonderful engineers in the Roman Empire who designed and constructed these magnificent bridges and amphitheaters some are still functioning until today. Then, the seminar moves to post-Calculus era in which the first modern school of Engineering in the World, L’Ecole Polythechnique, was established in Paris in 1794. The school was strongly supported by Napoleon and the greatest mathematicians and scientists of the nineteenth century were affiliated with it. Among the famous who taught there are Lagrange, Laplace, Poisson, Fourier, Cauchy, Poincare, Fresnel, Ampere, and Carnot. The first modern school of engineering in the United States is thought to be RPI in Troy, New York. It was established in 1824 by someone inspired by L’Ecole Polytechnique in Paris. In this introduction, I also very briefly refer to World leaders, famous people, and celebrities who happened to be engineers. Alfred Hitchcock (movie director and producer), Boris Yeltsin (ex-president of Russia), Williams Montel (American actor and TV talk show host), Lee Iacocca (American automobile executive), and William Hewlett (co-founder of the Hewlett-Packard Company) all have something in common. They all got engineering training and earned an undergraduate degree in Engineering! Such examples not only inspire students but also show them how important and rewarding an engineering education can be. When someone earns a BS in Engineering, this will open a wide gate for him or her. He or she can become a famous industry executive, an entrepreneur, a physician, a lawyer, a movie director, or even a president of a country!

Next, we move to define “Engineering”. I start by asking the attendees “What is Engineering?”. Some students volunteer and suggest an answer to my question that generates an interesting debate and discussion. After defining “Engineering”, we review what engineers actually do, and that will lead to a discussion about the various disciplines of Engineering (Civil, Mechanical, Aerospace, Nuclear, Electrical, Computer, Industrial, Biomedical,…). I found that this approach was much appreciated by the seminar attendees. It helps them decide on declaring their major. After all, our young students want to do things that they like and enjoy. In general, American teenagers have a much better idea what medical doctors and lawyers do in their profession than what engineers do. This is partly due to movies and popular TV series that portray role model physicians and lawyers, and the lack of similar TV series portraying engineers.

Then, we move to talk about the various jobs of an engineer. He or she can be in design, analysis, research, test, sales, etc. A graduate with imagination can work as a design engineer. Someone with analytic mind and who enjoys mathematics can end up as an analysis engineer. Someone with great communication skills and who likes to work with people can become a sales engineer. A graduate who is handy and who enjoys playing and fiddling with machines and equipment might find a test engineer the proper job for him or her. Contrary to what some people might think, certainly not all engineers sit in front of a computer screen and do computation all day. There is a wide variety of jobs and functions awaiting engineering graduates. Students who decide to study engineering are not photocopies of each other. They have different gifts, talents, interests, and desires and they are happy and excited to learn that there is an engineering function that fits everyone.

After showing the attendees how exciting it can be to become an engineer, and after going over the benefits and advantages of studying engineering, I move to the second part of the seminar: How to **succeed** studying engineering? Engineering education is highly rewarding but very demanding. It requires that students invest significant time, energy, effort, and sacrifice. I want to show them that they can certainly succeed. Success can be reached, but one has to both work on it and stay current with assignments week-by-week. I become a motivational speaker in the second part of the presentation! We define what "success" is. We show how it is important to set up goals in life (short term goals, midterm goals, and long term goals). We show how critical to stick to it and not to let adversity deter someone from accomplishing his or her goals. We show them how important it is to work hard and smart. Quoting the great American inventor and businessman Thomas Edison: "Genius is one percent inspiration and ninety-nine percent perspiration". I strongly encourage students to fully participate in the seminar, to ask questions, and to express their opinions and views. The questions attendees ask usually benefit everyone.

Outcomes and benefits of the seminar

The seminar that I have been giving for over ten years at the beginning of the academic year has not only been popular, but very useful and helpful to our incoming students. The feedback I received from students and the administration was excellent. The seminar also has contributed to improved retention in the school of engineering.

Reference

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WORKSHOPS

How to Record, Caption, and Publish a Video Tutorial in Under 30 Minutes

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Abstract

Video tutorials can be used by instructors for a variety of purposes. They can serve as a supplemental resource that targets difficult concepts, replace an in-class lecture when attending a conference, or be the foundation of alternative pedagogical models such as a flipped or hybrid course. It is now possible to create video tutorials easily using commercially available software, such as Camtasia Studio. Once created, the videos must be hosted on a server so students can view the content, and captioned for accessibility. In this workshop, the authors will demonstrate how to create and edit video tutorials using Camtasia Studio, upload the videos to YouTube, and caption the videos in under 30 minutes. Best practices for creating high-quality video tutorials will discussed as well

Increasing First-Year Students Success through Self-Regulation

Steffen Peuker
California Polytechnic State University, San Luis Obispo

Abstract

An innovative, best practices approach has been developed to increase the quality of the educational experience of first-year engineering undergraduate students. Typically, approaches to increase the nature and quality of first-year undergraduate education experience are focused on instructional and/or curricular changes. This new approach is different in that it focuses on what the students can do themselves to become successful, self-regulated students and henceforth graduate with an engineering degree. The approach teaches students “best practices” and how students can develop their own process to become successful within the higher education engineering environment. Engineering curricula is unique through the offering of “Introduction to Engineering” courses. The focus of these courses is generally not only content focused, but includes some focus on student development. There is no counterpart in the other STEM disciplines (Introduction to Physics, Introduction to Engineering Technology, Introduction to Chemistry, etc.). Where such courses do exist, they are content courses (Chemistry I, Physics I, Calculus I, etc.). There are specific objectives that can only be accomplished through engineering-specific freshman orientation courses. Among these are: (1) The opportunity to build first-year engineering students into a learning community and promote a high level of mutual support. (2) The opportunity to work to strengthen the commitment of first-year engineering students to their goal of receiving their B.S. degree in engineering. Many students that choose to major in engineering lack the strong commitment necessary for success in such a demanding field of study. (3) The opportunity to work on specific academic success strategies appropriate to math/science/engineering problem solving coursework. As one example, the importance of keeping up in one's classes is much more important in courses where

each new concept builds on previous concepts. (4) The opportunity to instill the value of participation in engineering-related, co-curricular activities such as engineering student organizations, pre-professional employment, engineering student competitions, and undergraduate research experiences. This workshop is facilitated by an experienced First-Year Engineering Educator and offers a collaborative interactive format for people interested in improving first-year engineering student success. Specific structured activities/discussions include:

- What is student success?
- How to advance first-year students to work to their full potential?
- Exploration of a student's reflection on how to be successful as a first-year engineering student.
- Implementing a project to facilitate the development of student self-regulation
    - Incorporate the project in existing courses/seminars
    - Collaborative learning strategies to support the objectives of the project
    - Grading solutions for high enrollment courses
    - Barriers for implementing the project
    - Available support material for the project
    - Joining the research effort – implement, assess, publish

PANELS

CSU's Course Redesign with Technology Initiative – Redesigning Bottleneck Engineering Courses

Angela Shih
California State Polytechnic University, Pomona

Abstract

Cal Poly Pomona (CPP) has one of the largest engineering programs in the U.S.A. with over 5,500 undergraduate students. Engineering education is under considerable pressure to include more and new materials to restructure course content using new approaches and technologies and to manage a spectrum of students with diverse backgrounds in spite of the reduced total number of credits for graduation. Most engineering curricula have become more intensive and thus students are required to spend more time for each subject. With limited financial support, an increasing number of students at CPP are working during the week. A heavy working schedule limits students' ability to take classes in certain days and times and impedes students' ability to seek help during regular school hours. These factors attribute to a high number of students retaking certain bottleneck courses, preventing students from moving forward with degree completion; overall, it delays graduation time. To combat the enrollment bottlenecks, the CSU Office of the Chancellor is supporting an array of programs to improve students' learning success through course redesign that responds to local campus needs. Since 2013, the Mechanical Engineering (ME) Department at Cal Poly Pomona has won a number of Course Redesign with Technology grants. Working in teams, ME faculty members have created hundreds of micro-lectures in video format, together with other educational technologies such as iClickers, smart-books, and online concept problems to redesign six bottleneck courses in Statics, Dynamics, Strength of Materials, Fluids, Thermodynamics and System Dynamics. The videos include lecture series by experienced senior ME faculty, demonstrations, simulations, derivations and homework examples. The videos are organized on the ME department website: www.cpp.edu/~meonline. In the first half of the panel, members from the Chancellor's Office Course Redesign with Technology Team introduce the mission and goals of its various programs and share success stories with the rest of the engineering educational community. In the second half of the panel, members from the Cal Poly Pomona course redesign team will share their experiences in course redesign, best practices, lessons learned and lead an open discussion with regards to how to reshape the future of engineering education utilizing emerging technology to actively engage students and to improve students' success.

McGraw-Hill Education: Supporting STEM Student Success

Thomas Scaife
McGraw-Hill Education

Abstract
As the Brand Manager for Engineering and Physics for McGraw-Hill Education, Dr. Thomas Scaife—who received his Ph.D. in Physics from The Ohio State University—develops and pursues strategies to create content and tools that support students as they develop the foundational skills needed to become professional engineers. He manages products related to courses in Physics, Mechanical Engineering, Aeronautical Engineering, Materials Engineering, Civil Engineering, Chemical Engineering, and Engineering Graphics. We are pleased to have Tomm join us for this conference.

Women & Men in STEM Higher Education: Navigating Family & Work-Life Balance

Cordelia Ontiveros, Lily Gossage
California State Polytechnic University, Pomona

Abstract
It's a timeless question: How can any of us make work and life balance? What happens when children are involved? Maternity and paternity leave—who takes it? Who are the primary care givers? Are there gender differences between female and male faculty, administrators? A study from the University of Massachusetts at Amherst and the University of Maryland at College Park, "Parental Leave Usage by Fathers and Mothers at an American University," challenges the idea that men in academia abuse gender-neutral parental leave policies to focus on research rather than parenting. Finding a lasting work-life balance—despite demanding professional careers, while tending to the needs of children, spouses, and aging parents—is a challenge for many career professionals. This panel of women and men (faculty and administrators), working in STEM higher education, representing a range of backgrounds, perspectives, and experiences, addresses this question.

POSTERS

Self-Watering Lawn System

Leonel Acosta, Mason Reynolds, Syed Mahed, Sabrina Listec | Ohlone College

Abstract

For the past 5 years, California has been in a severe drought. This drought has the potential to drive up food prices, put thousands out of work and devastate California's economy. One of the major solutions to this drought is to reduce residential water usage. We propose using an underground watering system that eliminates sprinklers and reduces residential water usage in California and the rest of America. We seek to replace the traditional sprinklers system with an underground watering system that efficiently delivers water up to the roots of a lawn, preventing the water waste normally associated with traditional sprinkler systems. Inspired by the simplicity of self-watering pots, we have designed an underground watering system that is capable of autonomously watering a small lawn for over 3 months. Our system uses a nylon wick to control the transfer and flow of water to the roots of the lawn, reducing water waste and usage. We are currently evaluating and fine-tuning the design to further reduce water usage. We are currently at 3 months on one fill but our goal is to have the system provide water for an entire year.

Belonging Uncertainty among Women in Engineering: Can Wonder Woman Save the Day?

Audrey Aday, Viviane Seyranian | California State Polytechnic University, Pomona

Abstract

Belonging uncertainty is a state occurring in academic settings when members of socially stigmatized groups are more uncertain of the quality of their social bonds and subsequently more sensitive to issues of social belonging (Walton & Cohen, 2007). Individuals experiencing belonging uncertainty may also experience ability uncertainty, or a sense of uncertainty regarding one's ability and competence in a given domain (Lewis & Hodges, 2015). One population that may be particularly discouraged by feelings of belonging uncertainty and ability uncertainty is women in engineering, given their underrepresentation in the field (Kokkelenberg & Sinha, 2010). This study aimed to determine whether undergraduate females in engineering report higher levels of belonging uncertainty and ability uncertainty than undergraduate females in other majors. Our results suggest they do. Based on data collected from 93 female undergraduate students at California State Polytechnic University, females from the College of Engineering ($n = 24$) reported lower levels of social belonging and higher levels of ability uncertainty than undergraduate females from the Colleges of Agriculture ($n = 25$) and Letters, Arts, and Social Sciences ($n = 44$). Preliminary findings and potential implications for academic achievement among women in engineering are discussed.

An Innovative Approach to Recruit/Retain Underrepresented Students in Engineering

Gerri Cole, Nicole Gutzke, Danielle Noriega, Nenetzin Rodriguez
California State Polytechnic University, Pomona

Abstract
Research shows that the number of women pursuing degrees in STEM (Science, Technology, Engineering, and Math) fields is disproportionately less than the number of men pursuing degrees in the same fields. [1-2] Cal Poly Pomona Women in Engineering (CPP WE) seeks to do its part in countering this disparity by engaging all men and women within the College of Engineering for the purposes of recruiting, retaining, and graduating greater numbers of female students. CPP WE focuses on four objectives: 1) engaging students through K-12 outreach activities for young women to increase awareness of and exposure to multiple engineering programs and their great impact on society; 2) providing a welcoming environment for prospective students to learn about College of Engineering and Women in Engineering programs; 3) retaining and graduating current female students by fostering a supportive community and enriching their experiences within the College of Engineering; and 4) creating a supportive network of alumnae to provide mentoring to current female students and to increase career and internship opportunities for students. This study will examine in greater detail the efforts of CPP WE as it pertains to objective 3. CPP WE strives to achieve these goals by providing program activities such as WE Chat, a program that provides female students within the College of Engineering opportunities to have lunch with female faculty from their respective departments in order to engage them in conversations about their career paths to engineering, challenges they faced, and advice to women pursuing engineering degrees.

Will Genetically Engineered Amphibian Skin Microbes Inhibit Growth of Batrachochytrium Dendrobatidis?

Marina De Leon*, Wei-Jen Lin*, Derek Sarovich^
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Abstract
The IUCN has deemed chytridiomycosis as the most devastating infectious disease among vertebrates (Gascon et al. 2007). Over 287 amphibian species are known to be negatively affected by *Batrachochytrium dendrobatidis (Bd)*, the fungal pathogen that causes a severe skin infection, chytridiomycosis, and as a result over 100 species have gone extinct since the 1970's (Kriger and Hero 2009). Recently, there have been global efforts to inhibit fungal pathogens by various means, for example; improving isolation and cloning of candidate genes that encode for the chitinase enzyme and the bisindole compound violacein (Mostafa et al. 2009). And a number of methods are available for applying bacterial transformation of genes that code for anti-fungal compounds such as violacein. Using information elucidated in previous studies, we propose that cloning and introduction of genes that encode for the anti-fungal compound violacein into a host bacterial strain will confer *Bd* resistance upon the host. Given the documented responses of the California Yellow-Legged frog to inoculation with *Janthinobacterium lividum*, a bacterium that

naturally expresses violacein, the native California toad *Bufo boreas* is expected to respond positively to modified microsymbionts used as a holistic method of chytridiomycosis treatment. To address if this is true, we have engineered a stable plasmid containing the violacein gene operon, and isolated skin microbes from two *B.* individuals that are known to lack antifungal bacteria of their own. We hypothesize that the violacein hybrid plasmid can be successfully transformed into a candidate species of native *B. boreas* skin bacteria. The genetically modified bacterium is expected to provide equivalent anti-fungal protection against *Bd* to that of *J. lividum*. *B. boreas* is an ideal model for this experiment because many of these toads are inflicted with chytridiomycosis in the wild. Populations are declining and in need of immediate aid. This species is susceptible chytridiomycosis and is not known to accommodate antifungal skin microbes. Three of these animals are currently being reared at the Cal Poly herp vivarium and have documented information about proper husbandry techniques and health background checks.

Interactive Effects of Nitrogen & Topography on the Distribution of Stipa Pulchra

Robert Fitch, Erin Questad | California State Polytechnic University, Pomona

Abstract

Anthropogenic nitrogen deposition causes numerous ecological problems such as reducing native plant species diversity [1]. After the rainy season, it has been shown that 90% of the nitrogen on hillsides is removed from within the top 25 cm of the soil and is most likely deposited down slope [2]. Therefore, a topographical gradient is created with lowland habitats containing higher levels of nitrogen and water compared to steep slopes. *Stipa pulchra* is a native bunch grass that is a dominant species in southern California grassland communities, and nitrogen deposition could explain its decline in abundance. High levels of nitrogen could affect *Stipa* directly by causing negative effects on its growth and reproduction, which has been demonstrated in coastal sage scrub communities [3]. Recently, it has been observed that *Stipa* occurs more frequently on moderate slopes and rarely in valleys and lowlands. The objectives of my experiment are to 1) analyze the differences in soil moisture and soil nitrogen created by a topographical gradient and 2) determine where in the soil moisture and nitrogen gradient is the most suitable habitat for the persistence of *Stipa pulchra*.

Fundamental Period Prediction for Steel Plate Shear Wall Structures

Amado Flores-Renteria, Jolani Chun-Moy, David Flores, Daniel Salmeron
Cañada College / San Francisco State University

Abstract

Building design specifications are developed in order to provide safety, reliability, and efficiency of building designs. Building codes are dynamic; changes or additions to seismic building codes are made as technology improves and statistical data is collected. In almost all seismic building codes, the design base acceleration is calculated using the natural period of vibration of the structure. Design codes have empirical equations to estimate the natural periods of buildings. However, current methods provided by ASCE 7-10 (American Society of Civil engineering)

approximate the natural period of structures that produce overly conservative values. The purpose of this project is to evaluate and optimize the method to approximate the fundamental period for steel plate shear wall structures by comparing empirical values with periods obtained through finite element analysis. Steel Plate shear Walls is a structural system where the main elements are Steel plate wall, horizontal boundary elements (HBE) and vertical boundary elements (VBE). Civil and structural engineers have used SPSW structures as they are a primary lateral force resisting system and resist horizontal shear. For this research project Mathcad and OpenSees were used to design and analyze structures varying in height, bay width, and shear resistance. The three different types of structures that were analyzed were type W, M, and N. The difference between these structures is the bay width. The categorization for each type is the following; W represents 20 ft. bay width, M 15 ft. bay width, and N 10 ft. bay width. For each classification of structure designs are completed to resist 100%, 85%, and 65% of the base shear applied to the structures. Revisions to the current approximation method are investigated utilizing data collected through finite element analysis in order to implement a more cost-efficient design code.

Leveraging CSU STEM VISTA AmeriCorps: "Mandatory Tutoring"

Lily Gossage, Noe Mora | California State Polytechnic University, Pomona

Abstract

While the California State University (CSU) establishes a minimum GPA of 2.0 for graduation, it is critical for students to aim for a "B" or better. Accruing "Cs" will neither expunge deficiency points nor prepare graduates for professional practice. Given CSU's Executive Orders 1037 and 1038 (academic policies on probation and unit limits for repeatable units/grade forgiveness, respectively), it is critical that upper-division students do well in major courses. With traditional tutoring approaches focusing on an array of courses, newer approaches were needed in order to identify and target "low completion-rate" courses. This approach reduces percentages of unsatisfactory student performance (e.g., grades of D, F, W). With limited staff, the Maximizing Engineering Potential (MEP): Center for Gender, Diversity & Student Excellence (College of Engineering, Cal Poly Pomona)—a service center designed to increase the recruitment, retention, and graduation success of historically under-represented minority, low-income, first-generation, and women students—sought partners to improve pass rates in key engineering courses. In July 2014, the Center Community Engagement, via the California State University (CSU) Office of the Chancellor, launched the first system-wide AmeriCorps VISTA (Volunteers in Service to America) program. The *CSU STEM VISTA: Building Institutional Capacity for a Stronger Baccalaureate* program builds the capacity of VISTA members and host site supervisors as leaders to foster cultural and systemic change in STEM at the college, department, and institutional level. AmeriCorps VISTA members serve on CSU campuses full-time for one year and focus on STEM student success efforts. MEP submitted a proposal and was awarded one-year of support. This poster gives an overview of how MEP leveraged AmeriCorps VISTA to establish a "Mandatory Tutoring" program. It showcases the steps, outputs, outcomes, and student monitoring approach used to implement mandatory tutoring.

Leveraging CSU STEM VISTA AmeriCorps: "Engineering Girls–It Takes a Village"

Lily Gossage, Tiffany Nguyen | California State Polytechnic University, Pomona

Abstract

Following a year of success with the *CSU STEM VISTA* program**,** the Maximizing Engineering Potential (MEP): Center for Gender, Diversity & Student Excellence (College of Engineering, Cal Poly Pomona)—a service center designed to increase the recruitment, retention, and graduation success of historically under-represented minority, low-income, first-generation, and women students—submitted a second proposal to the CSU Center Community Engagement; it was again awarded support. In accepting that socio-economic status—when viewed through the lens of race/ethnicity—is correlated with specific communities, this VISTA project recognizes poverty as one of the greatest barriers to academic success in the school setting. It tackles low STEM degree attainment by African American, Latino, and Native American via K-12 outreach. This poster illustrates the trials and tribulations of a unique K-12 outreach program, called "Engineering Girls–It Takes a Village" (a week-long summer residential program serving girls/mothers from "The Villages at Cabrillo," a Long Beach transitional housing program for homeless veterans, families, and youth). Beyond exploring the range of viewpoints about how best to help displaced communities of children, this poster provides a glimpse into the experiences of the VISTA member who grew both professionally and personally. It describes challenges experienced by the VISTA member as she helped develop and implement the program. It emphasizes the importance of leveraging extra support, including community partners such as the Society of Women Engineers, the Cal Poly Pomona Housing and Residential Life staff, and Southern California Edison (SCE), an engineering corporate partner.

EGR100 Project: Fields of Engineering Interactive Research

Janet Hamabata | California State Polytechnic University, Pomona

Abstract

This poster discusses how we utilize an assignment in EGR100, Engineering, Society, and You, where students create an interactive research poster to educate their fellow classmates and others about each of the Fields of Engineering Programs offered at our university. This team assignment integrates the "learn by doing" philosophy into the assignment by having the teams research various aspects of the field of engineering including research into some of the new technologies in the field and undergraduate research underway on campus. Students also are encouraged to make their posters interactive by adding QR codes on the poster that leads the viewer to a video, photo, or paper which provides more detail on a specific topic related to the field of engineering. The poster will detail the assignment requirements, some poster samples, and the grading rubric.

Building Student Success: A Multi-Intervention Academic Advising Approach

Victoria Hamdi | California State Polytechnic University, Pomona

Abstract

The California State University system in hopes of improving graduation rates, attach a student success fee to student tuition to help offset costs for tutoring, academic intervention initiatives and advising. During Academic Year (AY) 2014-15, the College of Engineering at Cal Poly Pomona, received funding to hire 3 full time professional staff advisors to help strengthen an existing first year advising program. Upon the hiring of 3 advisors, and 1 existing advisor, an overhaul of advising within the college was done with the development of the Engineering Advising Center (EAC). The college boasts a student population of 5,500 students between bachelor and master degree programs. Over the course of two years, much change has been done to create a balance between faculty and professional staff advising to help students graduate along with developing key career development plans

Project Study: I-15/Limonite Ave. Interchange–A Partnership with Caltrans District 8

Robert Harmon, Russell Walker, Mario Garcia-Gillespie, Xudong Jia
California State Polytechnic University Pomona

Abstract

This project analyzes the design for the I-15/Limonite Avenue Interchange in Riverside County between the cities of Eastvale and Jurupa Valley. This consisted of first analyzing the existing interchange, determining its viability now and 20 years from now,, and looking into different alternative layouts. Secondly, these alternatives were designed and analyzed on the basis of traffic, geometric design, and environmental impacts. A traffic analysis looked into lane configurations (car and bike lanes) as well as intersection types (stop, yield, or signalized). The geometric design and feasibility was based on local, state, and federal design standards. Finally, the environmental analysis looked at the unique area and the impact each alternative would have on that environmental. After finding the existing interchange deficient for the 2040 time period we examined a multitude of different alternatives. A rigorous analysis and feasibility study produced only two viable alternatives: a Partial Cloverleaf and a Diverging Diamond Interchange. Both being possible, they were compared using a weighted matrix which considered various elements of each including: cost, benefit, constructability, local circulation, and other elements. With all these factors considered the Partial Cloverleaf design was chosen as the preferred alternative with its ability to handle traffic (vehicular, bike, and pedestrian), costing the least, and providing the most environmental benefits.

Preparing Students to Work in Capstone Teams

Matthew Haslam | Embry-Riddle Aeronautical University

Abstract

At Embry-Riddle Aeronautical University, all aerospace and mechanical engineering students are required to take a two-semester senior capstone course. Students complete their design and build or test projects in teams that typically range from 6 to 12 students. This poster reports research into how well senior students are prepared to work collaboratively in the capstone courses. Initial interviews were conducted with 9 out of 19 design team leads (DTLs) in the seven AE and ME capstone courses offered during the Fall 2015 semester. Key findings from these interviews include the following:

- Lower level engineering courses require students to work in teams, but students reported that instruction on how to collaborate in team settings is not provided in these courses.
- While some students had developed effective strategies for working in teams, they reported their training predominantly came from involvement in extra-curricular projects.
- Typical team projects in engineering courses involve 3–4 students for a few weeks; students were not prepared to work on a semester-long project involving 6–12 students.
- DTLs felt unprepared to discharge successfully required duties, experienced difficulties making assignments, motivating members, and ensuring quality among members.

Further research to be completed before the conference will involve the following:

- Interviewing the remaining 10 DTLs.
- Surveying all students in seven AE and ME capstone courses regarding preparation for and ability to work well in capstone teams.
- Documenting team assignments required in pre-capstone engineering courses.
- Determining what instruction provided in pre-capstone engineering courses regarding working in teams.

Imaging the Los Angeles Basin through Modeling of Seismic Waveforms from a Temporary High-Density Deployment (Work-in-Progress)

Michael Herrman, Jascha Polet | California State Polytechnic University, Pomona

Abstract

A passive source seismic experiment termed LASSIE (Los Angeles Syncline Seismic Interferometry Experiment) was conducted from September to November of 2015. This experiment was a collaboration involving academia (UCLA, Cal Poly Pomona, Caltech), industry (NodalSeismic, California Resources Corporation), and government (USGS) where a total of 73 broadband seismometers were deployed to collect high density seismic data in the Los Angeles basin (LAB) and surrounding area. Cal Poly was responsible for the installation and maintenance of 8 of these stations over the two month deployment. Our research will use the data collected from LASSIE to try and refine current velocity models of the Los Angeles using a full waveform modeling approach. To this end we will compare seismograms recorded by LASSIE for 53 earthquakes and quarry blasts located by the Southern California Seismic

Network (SCSN) that occurred within or near the LAB during the deployment period to synthetic seismograms generated by the Frequency-Wavenumber (FK) code developed by Zhu and Rivera (2002).

San Dimas Experimental Forest Watershed Modeling

Kevin Hernandez, Chris Thomas, Seema Shah-Fairbank, Kenneth Lamb
California State Polytechnic University, Pomona

Abstract
The United States Forest Service has used the San Dimas Experimental Forest (SDEF) for various watershed related research. This study focuses on Bell Canyon, the upstream canyon of the SDEF Big Dalton Watershed. The project's objective is to simulate the hydrological processes of Bell Canyon through a scaled physical model. This model has educational, research, and outreach applications through the model's comprehensive visualization of runoff and various hydrological characteristics within a watershed such as slope, roughness, and travel time. Students can observe the natural watershed process to better understand concepts in hydrology. Research can be conducted to investigate the relationships between hydrologic variables. Finally the public can be better educated through outreach efforts that incorporate the model. Furthermore, the physical model will be complemented by a computer model created through the Hydrologic Engineering Center Hydrological Modeling System (HEC-HMS) software to assure calibration and validation. The computer model will aid in the development of the physical model and can aid in understanding the hydrologic processes of the physical model. The physical model will represent and measure the properties of rainfall, landscape surface, slope, and outflow as accurately as possible to highlight the relationships between these characteristics. To test the accuracy of the physical model, its outflow will be compared to a HEC-HMS model and actual measurements from the Bell Canyon watershed. With a complete physical model supported by a computer model and field data, materials and lessons can then be developed to supplement the physical model in the education of the public, students, and government officials so they can understand watershed characteristics.

Engineering Abroad Service-Learning Program: Forging a New Paradigm for Student Engagement/Success through Unconventional Academic Experiences

Kelli Horner | Cabrillo Community College

Abstract
The engineering profession is struggling to attract sufficient students into engineering fields despite the well-documented career opportunities available to engineers. In 2013, the Engineering Abroad Service-Learning Program (EAP) was established at (name of college), forging a new paradigm in engineering education and an extremely unique opportunity for 2-year engineering transfer students. The EAP encompasses more than one full academic year, beginning with an application process (spring prior). The following fall semester, weekly preparatory meetings lead by two Engineering faculty, guide fourteen students in exploration of Guatemala's culture, health and safety of traveling abroad, and perform preliminary research and

design of various water supply projects, as well as other high priority projects designated by the small village of Vuelta Grande. The two-week abroad experience in Guatemala, between the fall and spring semesters, consists of working with the adult leaders of the village to design, procure material, build, and test the projects. During the spring semester following the experience, weekly culmination meetings allow the students to reflect and document their experience in a series of presentations to the college and the local professional community. The EAP offers an unconventional, hands-on, global opportunity with measurable outcomes of increasing engineering student engagement and success. The quantitative component will compare the academic performance and degree progress of students participating in the past three EAP cohorts to corresponding outcomes achieved by students in a comparison group using the standard technique of propensity score matching. The qualitative component will include self-assessment and focus group data conducted with the EAP participants. Particular attention will be paid in both the surveys and focus groups to capture differences in how the experience affects underrepresented students. Results from the study of this program could also serve as an important catalyst for attracting corporate sponsorships that would sustain future efforts at (name of college) and, more importantly, establishing EAPs at other 2-year institutions.

Incorporate Engineering Component in Learning about Solar Energy via Dye-sensitized Solar cells: Secondary Science Education (Work-in-Progress)

May Yin Melody Isabela | California State Polytechnic University, Pomona

Abstract

The use of the New Generation Science Standards to teach engineering concepts will help encourage current science educators develop lessons that integrate technology, mathematics and engineering for K-12. Incorporating problem solving skills and engineering design while investigating natural phenomenon, the scientific inquiry process becomes meaningful for students. In this research, the main focus is for students to learn about the principles of conservation energy, electromagnetic wavelengths with various natural pigments, the movement of electrons, and the concept of photons, and experiment with the conversion of solar energy into electrical energy by using Dye-Sensitized Solar Cells (DSSC) through types of fruit juices. Students will learn to evaluate/measure the amount of solar energy that can be captured by the color pigments/chlorophylls. This experiment also involves an understanding of engineering design as students need to arrange several solar cells to maximize electrical currents to power up a small LED light while simultaneously investigating the function and the importance of chlorophylls in the process of photosynthesis. A pre-lesson survey and a post lesson survey will be conducted to inquiry student’s understanding about engineering design in this experiment and their interest in pursuing careers in the field of engineering.

Observed Improvement in Student Performance as a Result of the Introduction of Group Discussion in Lectures

Laila Jallo | California State Polytechnic University, Pomona

Abstract

Student learning is influenced by effective teaching methods that are student-centered. In this project, group work that incorporates group discussion as a teaching and learning tool to encourage student engagement was used during class lecture in two Introductory Chemical Engineering courses. On the first day of class the students were randomly placed in groups of 4 and instructed to sit together for all lectures. They were instructed to create group answer cards with letters A to E, which should be brought to every lecture and used to answer concept questions embedded in the lecture powerpoint. During lecture, after covering a specific concept, groups were given between a minute and two to discuss concept related questions and each group shows their answer in unison at the instructor's prompting. Irrespective of the percentage that got the right answer, the instructor systematically explains the answers, spending more time on difficult questions and less on easier ones. Preliminary results have shown an improvement in student performance on examination results compared to last year, indicating the benefit of peer interactions in conceptually challenging lectures in an Introduction to Chemical Engineering course. In addition, it was observed that student performance was generally consistent across different sections of the classes compared to last year. This could be attributed to the consistency of presentation of lecture as well as peer interactions during lectures. A student assessment of learning goals (salg) survey showed that students overwhelmingly liked working in groups.

The Impact of Cultural Value and Cognitive Style on Web Usability

Jae Jung, Jae Min Jung, Sonya Zhang | California State Polytechnic University, Pomona

Abstract

Web usability measures how a website is optimized based on its user's perspective toward their goals. To date, most of studies have focused on either a methodology to measure web usability or its users' behavior itself. There has been a paucity of research examining why different individuals perceive the website differently. However, it has been well known that cultural values play a significant role in influencing individual's values, beliefs, emotions, and behaviors. Thus, this research focuses on the role of thinking style stemming from culture on the users' perceptions and preferences for their website usage. To this end, this study conducted secondary data research by thoroughly searching online databases in information system, human-computer interaction, social psychology and marketing (i.e., ABI/INFORM and ACM Digital Library). This effort yielded 45 relevant articles from prominent journals such as Information System Research, Management Science, and Social and Behavioral Science. Review of those articles lead me to suggest that the Microsoft Usability Guidelines (MUG) be used to evaluate websites and propose a number of propositions drawing on Hofstede's cultural values and Nisbett's cognitive style framework. This research contributes to the information systems and marketing literatures by identifying under-researched areas in an effort to stimulate research.

A Written Guide for Women in Physics Groups: Membership, Activities, and More

Lauren Keyes, Nina Abramzon, Alexis Knaub
California State Polytechnic University, Pomona/ Western Michigan University

Abstract

Many Women in Physics (WIP) groups exist on college campuses across the United States to support women as they pursue degrees in a field in which they are typically underrepresented. However, there are limited resources in existence that help these groups navigate the complex issues that face women in physics. As a first step to correct this problem, a written guide is being developed to aid physics students and faculty in the creation and maintenance of WIP groups. It is based on data collected in surveys of one hundred people and interviews of ten people from nine different campuses in the United States. The surveys and interviews were independently analyzed by two researchers who each developed a system of codes to conceptualize, identify themes within, and provide meaning to the data. We present initial findings on the reasons why students join WIP groups, activities most valued by group members, and challenges these groups commonly face. It was found that WIP groups primarily act as social settings for women to meet other women physicists and as support systems, in which the passing down of information in mentor/mentee relationships is highly valued. It was also found that a common challenge encountered by these groups is low membership and participation. These findings are compared to what has been observed in literature to determine whether or not it is supported by previous research. Finally, this information is put into the context of the written guide and shown how it can be of use to WIP groups.

Modes of Feedback in Design Review Process: Implications for Utility and Effectiveness Based on Student Gender and Tone

Gordon Krauss, Laura Palucki-Blake | Harvey Mudd

Abstract

At its best, a design review or presentation delivers actionable information on the quality of the design artifact and design process to the designers and other involved stakeholders. Reviewers may not deliver candid, objective information if, as in the case of a design course, peer review accentuates issues of review reciprocity and social cost, interfering with a reviewer’s ability to provide candid feedback. Similarly, designers may defend their design artifact and process rather than receive and apply critique. This can be true in any context, but may be particularly true when presenting to an audience that includes the individual responsible for their grade. In this study, the authors examine the traditional oral question and answer method of providing feedback and compare it with written feedback using an online tool. Of further interest is the breakdown by gender on the perceived effectiveness of each type of review process (oral vs written). Three sections of approximately 20 students in an introduction to design course participated in this study. Sections were divided between those providing written (only), written and oral, and oral feedback. Each section was asked to provide feedback during a design review and final design presentation. Each designer was given the feedback in written form (including

any oral questions which were transcribed). The designers identified the three best and worst comments and were asked to rate the comments topic, relevance, application to future work and tone. Later, each student evaluated the design review process. The authors observed statistically significant differences between male and female students in their perception of written and oral feedback and different points in the design process, including important questions, "The feedback was open and candid," and "I received excellent feedback." Associations between the comment tone, relevance, and impact on future design are also examined. The research implies changing that the method of feedback from the traditional oral question and answer session to written feedback during a design review or design presentation may be more inclusive of women students. The correlation between a comment's perceived tone of feedback and its usefulness in the design process suggests that training in both appropriate framing of a comment for reviewers and parsing content from tone for designers may benefit feedback overall.

Collaborated Multiple Campuses Teaching by Converged Network Technologies

Alex Leung | Devry University

Abstract

With college enrollment consistently declining since 2011, many higher educational institutes with 3000 students or less are facing problems to offer on campus classes due to shortage of students. Online distance learning seems to a good alternative, but lack of human interaction is always a major drawback. As converged network technologies became more affordable and accessible, collaborated multiple campuses teaching using remote distance learning has become a reality and may offer a solution. Collaborated multiple campuses teaching preserves the traditional face-to face classroom experience yet offers the virtual interaction with human elements at a distance. Students' personalized learning can also be maintained. Students can take control of their learning through access to a recorded audiovisual database for lecture and lab information, anytime and anywhere. Since 2012, DeVry University has risen to the challenge of providing collaborated multiple campuses teaching by videoconferencing in Advanced Technology Classroom (ATC). By January 2016, a more powerful Virtual Connected Classroom (VCC) will be deployed. VCC has many state-of the-art advanced features such as, interactive whiteboard across campuses, voice sensitive-driven video camera, auto focus HD camera for lab components and textbook display, etc. Both ATC and VCC are incorporated with interactive video, audio, data, and wireless mobile access technologies for collaborated distance learning. This poster session will focus on the advanced features of converged network technology classroom and will also include the following topics:

- An overview of classroom videoconferencing for distance learning
- DeVry University network
- Rationale for collaborated multiple campuses teaching
- ATC, and VCC technical features
- Successful outcomes and challenges
- Best Practice and lesson learned

Vital Signs of the Planet: A Professional Development Program for High School and Middle School Science Educators

Hernan Lopez | California State Polytechnic University, Pomona

Abstract
The NASA/Jet Propulsion Laboratory (NASA/JPL) InSight E/PO team and Southern California Earthquake Center (SCEC) along with California State University San Bernardino (CSUSB), and USGS-Pasadena engaged science educators in the Vital Signs of the Planet Professional Development Program, an NGSS aligned middle school and high school research experience and curriculum development program offering strong connections to STEM research. The program fellows interacted with scientists at Caltech, JPL, and USGS-Pasadena. They were briefed on topics including seismic hazards, the Quake Catcher Network, Earthquake Early Warning Systems, GPS, and earthquake information technology at Caltech and USGS. While at JPL, they met with researchers in their labs and were briefed on the InSight (Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport) mission to Mars by the mission Principal Investigator. An important aspect of this experience was participation in a 4-day field research component, wherein teachers contributed to ongoing research on tectonic plate deformation along the San Andreas fault lead by Sally McGill of CSUSB. They plotted data collected through GPS and utilized modeling programs for analysis of slip rate around the fault. The combination of these experiences lead to the development and implementation of four lessons in Earth science and physics. Using the Lesson Study model, a professional development process where educators systematically examine their practice, participants identified where their students encounter learning challenges. Taking into consideration the Next Generation Science Standards (NGSS) and the Common Core State Standards, teachers collaborated to develop lessons that focused on what teachers want students to learn rather than on what teachers plan to teach.

Creation of Polymer-Fiber Composites through Use of Fused Deposition Modelling

Colin McGill, Alex Furlanic, Shane Sharp | Cañada College

Abstract
In recent years the 3D printing industry has expanded from standard polymer based filaments, such as polylactic acid (PLA) and acrylonitrile butadiene styrene (ABS), and developed methods of printing composite-based materials. The use of composite materials in 3D printing has primarily been accomplished by incorporating particles of a material in a standard thermoplastic filament. During a 10-week internship program four undergraduate community college engineering students were assigned the task of developing a composite material by surrounding fibers with a 3D printed matrix to improve the qualities of a standard print samples. To find an optimal combination for fiber-matrix composites, interns used a multitude of fibers and filaments to test which combination yields the best ultimate tensile strength, modulus of elasticity, %elongation, maximum stress, maximum stress per unit mass, and toughness. The fibers covered in this internship are unidirectional carbon fiber, S-glass cloth, and E-glass cloth. These fibers were surrounded by a 3D printed matrix made out of various filaments including; PLA, ABS,

carbon XT-CF20, Ninjaflex, and Semiflex, that incorporated with the fibers to reinforce the composite. A procedure was developed for printing composite dog-bone samples with a single layer of fibers embedded in the middle of a 3D printed matrix, which was tested using an Instron tensile tester. When compared with the control samples certain combinations of the composite materials tested showed positive trends for one or two specific qualities while performing worse than the control samples on other tests. This range of outcomes suggests further research into the composite 3D printing industry would be beneficial in determining if simple composites should be used as a substitute for typically printed thermoplastic samples.

Detection of Cyanobacteria and their Toxins for Safe Algae-based Feed Production

[1]Joe McHugh, [1]Alyssa Sancio, [1]Shelton E. Murinda, [1]Marcia Murry, [2]Gregory Schwartz, [2]Trygve Lundquist, [3]A. Mark Ibekwe
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Abstract
Our goal is to develop molecular techniques to identify classes of cyanobacteria for early toxin threat detection and control before the growth becomes toxic. This screening is part of a larger sustainability project focused on converting dairy cow manure effluent into a fast-growing, algae-based, safe animal feed crop. The algae are produced in paddle-wheeled model ponds on the dairy farm which could become contaminated by toxic cyanobacteria. To ensure the integrity of our analysis, multiple species of pure cyanobacteria cultures were grown and their DNA purified. The *16S rRNA* and *rpoC1* gene sequences were targeted for their universal detection of cyanobacteria using PCR. To distinguish cyanobacteria species that have the potential to produce toxins, five gene clusters in the toxin synthesis pathways were targeted: *mcy* (microcystin), *nda* (nodularin), *cyr* (cylindrospermopsin), *ana* (anatoxin-a) and *sxt* (saxitoxin). PCR-amplified fragments were separated using agarose gel electrophoresis and sequenced. *16S rRNA/rpoC1* PCR assays allowed for positive identification of quality control strains (QC) and exhibited the sensitivity and specificity to discriminate against multiple genera of non-cyanobacteria strains. Within our QC strains we have identified strains that indicate potential to produce microcystins, and anatoxin-a. Toxin production was detected directly using Abraxis/Beacon ELISA kits. Our future goals are to correlate presence of toxin genes with toxin production as well as their quantitation with qPCR. This protocol will routinely detect and identify the presence of cyanobacteria species that could produce toxins in algae production ponds and allow for their control in algae-based livestock feed operations.

Repeatability Performance Evaluation of RTK and VRS Positioning Networks: A Case Study at Cal Poly Pomona

Rudy Mislang, Omar Mora | California State Polytechnic University, Pomona

Abstract

Real-Time Kinematic (RTK) positioning with Global Positioning System (GPS) is an important surveying and mapping technique used today. The repeatability/precision of RTK positioning is an important component of why it is consistently used. Recently, interest has grown, and use of Virtual Reference Station (VRS) networks has become common. VRS networks use GPS data from Continuously Operating Reference Stations (CORS) that are continuously connected and generating real time corrections to improve precision of three dimensional positioning. As a result, the networks create a VRS a few meters from the rover location together with corrections. The rover uses corrections from VRS as if they were coming from a real reference station. In this study, a test is proposed to evaluate performance of the VRS system covering the Cal Poly Pomona campus used to acquire high accuracy positioning. In particular, we will focus on the repeatability of the vertical component, which is the least accurate, being 2 to 3 times worse than the horizontal element. To determine repeatability of VRS and RTK positioning a comparison will be performed between the observed data for both techniques. The analysis will evaluate the difference between the two statistically to determine if repeatability of observed positions using VRS and RTK systems are within the allowed surveying and mapping practice tolerance.

Navigating a Novel Approach for Intrusion Detection in Time Series

Monica Mixco, Zekeriya Aliyazicioglu, Ha T. Le, Rajan Chandra
California State Polytechnic University, Pomona

Abstract

The swift development of computer networks has transformed the prospect of network security. An easy accessibility may cause computer networks to be defenseless against frequent and overwhelming threats from intruders. Researchers have developed Intrusion Detection Systems (IDS) which are capable of detecting attacks in numerous platforms. Intrusion Prevention Systems (IPS) have evolved to restrict possible attacks in passive networks. IPS can be seen as a step up upon firewall. It can make access control decisions based on application content instead of its IP address or ports as it happens in case of traditional firewalls. This paper presents an overview of IPS for a particular application. Based on the data contents of this application, it decides on particular windows of data to be nominal or an intrusion. This analysis was started by analyzing all series of known data patterns, we have evaluated different characteristics of data e.g. mean, variance, PDF(probability distribution function). Based on these result we were able to minimize the set of data to only non-redundant and useful information. This IPS is trained using Kalman filter with actual time series and also with certain possible anomalies which may occur. Kalman filter is suitable choice as it estimate the state, determine the prediction error and applicable for unknown time varying systems. A decision criterion is made using the variance of a small window of data, which is suggested to be the strongest to differentiate between real data

and anomaly. We want to create a method for the complete decision of threshold for anomaly detection.

e-Learning: Electric Circuits & MATLAB Programming for Engineering Students

Woonki Na | California State University, Fresno

Abstract
The electric circuit is a traditional course for engineering students. Also, MATLAB programming course is very common in most of the engineering programs. These courses can be used in the first and second year of the engineering students, and could be a big challenge for the students who do not have much of the basic background of electric circuits and programming skills. For an easy adoption of these courses using online tools, this paper introduces formats of these two essential courses that involve online tools such as Blackboard and Socrative, and compare the results from the traditional courses, not much used in the online tools with these heavily online based courses in terms of student success, participation, satisfaction and completion rate. Also since this electric circuit course is one of the tablet initiative courses offered by Fresno state university, a course survey for the tablet based course was carried out. Besides, the exit surveys show the challenges of these two online embedded courses.

Surface Energy Determination through Contact Angles and Cold Plasma Treatment

Jase Nosal, Annah Ramones, Yasmina Rousan, Elline Hettiaratchy, Nina Abramzon
California State Polytechnic University, Pomona

Abstract
Past studies have demonstrated that increasing the surface energy of metal materials improves their resistance to surface biofilm growth. We investigate surface energy modification with radio frequency-generated cold atmospheric pressure plasma composed of helium and oxygen on various metal surfaces as a means of reducing biofilm growth on metal implants within the body. We treated stainless steel using a commercial Surfx shower head type plasma reactor to determine the dependence of surface energy on the direction of plasma flow (parallel versus orthogonal to the surface) and on exposure time. Water droplet contact angle was used as a measure of surface energy and plasma molecular spectra were measured with a spectrometer throughout treatment to monitor the concentrations of reactive oxygen species which are known to prevent bacterial growth. Once the treatment times required to reach maximum surface energy levels were determined for both orthogonal and parallel processes, different time intervals were allowed to elapse between treatment and surface energy measurement to determine how long the treatment remains effective before the energy begins to decrease. For the materials tested, we present comparisons of surface energy for different plasma flow directions and exposure times, and discuss the post-treatment longevity of the elevated surface energies.

Increasing and Retaining Minority Students' Participation in the STEM Fields

Rianne Okamoto, Larissa Davila, Vanessa Davalos, Mónica Palomo
California State Polytechnic University, Pomona

Abstract
The Science, Technology, Engineering, and Mathematical (STEM) fields do not usually attract first generation, low-income, and/or minority students (such as women, Hispanics, and African American, etc.). There are many ways to increase the number of minority student's participation in STEM careers, one of the most common methods is the implementation of outreach programs that introduce K-12 students to STEM related activities. This study shows the results of a service learning course that uses outreach activities as a way to increase the participation of minorities in the STEM fields. Engineering students immerse themselves in the K-12 classroom and become mentors and teachers of middle school students while leading the development of STEM activities. The mentorship experience culminates with an evening event at the University Campus where the college students welcome K-12 peers and their parents for a night of fun STEM workshops and activities. Via this service learning experience participating college students have been able to engage in diverse scholarly activities beyond the K-12 experience, which has increased motivation to continue the pursue of the engineering degree.

Advanced Water Purification System, Utilizing Renewable Energy

Kurt Paul, Daniel Vera, Hector Cardenas, Victor Nguyen
California State Polytechnic University, Pomona / Hydren, Inc.

Abstract
Reclamation and reuse of waste water plays a vital part in cutting the gap between our water supply and water demand. Several water reuse technologies are introduced within the literature. Each of these technologies has been proven to be effective in treating the water to acceptable water standards. Water reuse can be found everywhere from a local, national or global level. Described in the literature is also the growth trends and how water reuse has been gaining popularity over recent years. Another topic of discussion that is covered within the literature review is the amount of waste produced by water reuse as well as different ways to treat and take care of this waste. Lastly, another main topic of discussion is the public perception on indirect and direct potable reuse. The public has a negative view point on reusing water for drinking water purposes. This negative perception stems from the fact that they are drinking water which was once waste. This negative view is due to a lack of knowledge by the consumer. As the drinking water that comes from waste is just as clean as water that is pumped from the ground water table. The main emphasis of this study is to inform the public on water reuse and its benefits in solving the water supply shortage that is being experienced in present day.

Developing a Software Environment to Organize, Process, and Implement Gesture Recognition using Electromyography and Inertial Measurement Unit Data

Muslim Razi, Lina Tsvirkunova, Jeremy Chow, Rebecca Reus, Ian Donovan, Amelito G. Enriquez, Wenshen Pong, Xiaorong Zhang
Cañada College / San Francisco State University

Abstract
Gesture recognition is a method to improve the intuitiveness and efficiency of direct communication between humans and technology. It is instrumental to applications such as prosthetic limb control, stroke therapy, and virtual reality gaming. The electromyographic (EMG) signal is an effective bioelectrical signal for expressing movement intent and has been widely studied for gesture recognition. However, it is still an underdeveloped field with few robust and reliable mobile gesture recognition platforms commercially available. This project aims to develop a software research platform for gesture recognition by interfacing with a commercial armband called Myo (Thalmic Labs), which measures signals from 8 EMG sensors and an inertial measurement unit (IMU). The project is led by a team of four undergraduate students mentored by a faculty advisor and a graduate student during a 10-week summer internship. Our approach to gesture recognition is to collect Electromyography (EMG) and Inertial Measurement Unit (IMU) data then process and classify them as user commands using mathematical algorithms. The developed software platform provides a user friendly GUI that collects raw EMG and IMU streaming data from the Myo armband, extract useful features from the raw data, recognize user's gestures in realtime by using various pattern classification methods, and provide visual feedback to the user. The developed modularized software can be used as a basic research platform for gesture recognition, which can be easily expanded in many ways including applying various feature extraction methods and pattern classification algorithms, and interfacing with gesture controlled applications and devices.

Logic Design using Spin Transfer Torque Technology for Hardware Security Applications

Juan Rodriguez Gudiel[1], Taimoor Tariq[1], Michael Gamarra[1], David Alvarez[1], Hamid Mahmoodi[2], Darya Almasi[2] | [1]Cañada College / [2]San Francisco State University

Abstract
Spin Transfer Torque (STT) is a relatively new technology with a promising future in hardware security. One cell of Spin Transfer Torque Random Access Memory (STTRAM) consists of one NMOS transistor and Magnetic Tunneling Junction (MTJ), which allows storing information magnetically. This technology—due to its non-volatility, CMOS compatibility and scalability—offers a unique opportunity for enhancing hardware security. This new technology can be developed to create STT-LUT (Lookup Table) circuits that can emulate any type of reconfigurable logic-based circuit. This STT-LUT implementation is a programmable circuit that can protect the intellectual property of a design by allowing the hardware to hide its identity from hackers who may attempt to reverse engineer. The purpose of this research is to improve STT-LUT circuit design by observing the effect of changing high and low resistance of MTJ, which

are used to calculate the Tunneling Magnetoresistance (TMR); it has been found that a larger TMR value will decrease the overall power and delay of the circuit. The end result of the research project will further aid to bring faster, low-power and economical STT-LUT circuits. Implementing part of a logic circuit in a programmable form offers opportunities for power and performance improvements via dynamic hardware reconfiguration. Research experiences on such advanced technologies are typically not available for community college students. This poster highlights the results research done by a group of community college students as part of a ten-week summer research internship program designed to increase student self-efficacy in engineering among underrepresented minority students and enhance their success in transferring to a four-year institution to pursue engineering degrees.

Detecting Anomalies in Irregular Signals using K-means Clustered Signal Dictionary

Guadalupe Talavera Reyes, Zekeriya Aliyazicioglu, Rajan Chandra
California State Polytechnic University, Pomona

Abstract
The critical nature of satellite network traffic provides a challenging environment to detect intrusions. The intrusion detection method presented aims to raise an alert whenever satellite network signals begin to exhibit anomalous patterns determined by Euclidian distance metric. In line with anomaly-based intrusion detection systems, the method presented relies heavily on building a model of "normal" through the creation of a signal dictionary using windowing and k-means clustering. Our preliminary results demonstrate the clustering technique used has great potential for intrusion detection in non-periodic satellite network signals.

From Degeneration to Regeneration? Inquiry into the Environmental, Social, Economic Viability of California's Salad Bowl & Central Valley

Gilbert Verdugo, Kyle Brown | California State Polytechnic University, Pomona

Abstract
The counties of the San Joaquin Valley and the Central Coast of California comprise the most prolific agricultural region in the United States. In 2012, these counties combined for over $35B in gross revenue from agricultural production, much of it contributing to transnational exports. At the same time, this region faces significant environmental challenges in the form of disproportionately high pollution burdens, significant social challenges associated with poverty, educational attainment, housing and political marginalization, as well as long-term economic challenges about the continued viability of production consistent with historical levels, particularly given persistent droughts and other implications of climate change. In this poster, we analyze this region through the three-part lens of sustainability, examining environmental, social and economic indicators to assess the long-term prospect for the region as a continued leader in agricultural production, and implications for the environment and its people. The results prompt many relevant questions about the continued subsidizing of agricultural exports in the face of declining water resources, the environmental consequences of such an economy, and formation

of inequalities across socio-economic categories resulting from distribution of environmental burdens and economic opportunity. This analysis contributes to the growing literature on cases of decline and collapse in the face of changing environmental, social, and economic conditions, and poses thoughtful discussion about regenerative futures for such communities.

The Best of All Worlds? Teaching Learner-Centric, Object First Java Programming

Kendra Walther, Trina Gregory | University of Southern California

Abstract

This poster describes the experience of taking a lecture-focused traditional procedural first programming course in Java and redesigning it as a hybrid style objects-first programming class. Taking best practices, we combined several tools and strategies to build a cohesive introductory programming course that allowed our students to truly understand Object-Oriented Programming (OOP) principles from the beginning of the course. Rather than flipping the class, students used an interactive online textbook that allowed them to learn and practice topics on their own timelines. Students were encouraged to experiment and to learn how they learn, and then they could intelligently use the textbook to either introduce new material or to reinforce lecture topics. Lecture time was critical to the course, and during lectures, we presented material to stimulate all three main learning styles (auditory, visual, and kinesthetic-tactile learners). Lecture time included traditional PowerPoint presentations but also focused on live coding examples and demonstrations where instructors modeled their thinking while demonstrating new coding concepts, and active participation where students coded by themselves or in pairs. Instead of programming in a procedural way with a “main” method, we used the BlueJ programming environment, which is a purely teaching environment. By starting with BlueJ, students were able to avoid using “magic words”, and instead could focus on good object-oriented programming principles from the beginning. By combining best practices into one cohesive learner-centric course, students ended the semester with a stronger object-oriented programming background than any previous semesters.

Solar-assisted Inland Brackish Water Desalination System

Sean Yazdi, Andres Ceja, Abraham Morales, Vien Nguyen
California State Polytechnic University, Pomona

Abstract

Conservation of potable water has become a critical issue during southern California’s drought crisis. Public awareness about this issue is on the rise, along with technology needed to purify various water resources. Our team is committed to developing an efficient water desalination system and increasing public awareness about the necessity of engineering new innovative tools to produce cleaner water. According to the United States Geological Survey (USGS), brackish groundwater is located under a large portion of southwestern states. This water can be cleaned and used to relieve the increasing drought crisis in southern California. Desalination and purification of inland brackish water powered by solar energy can supply local regions with

potable water while maintaining a zero carbon footprint. Our team constructed a bench-scale desalination machine that can be further developed into a pilot-scale water purification system. Our process uses concentrated solar power to heat water and reverse osmosis to desalinate water. Reverse osmosis technology that utilizes both photovoltaic panels to power the system and concentrated solar panels to directly heat brackish solution prior to desalination is a useful way to harness solar energy to produce drinkable water. The hydraulic system brings brackish water to 250 psi and directs the flow through a reverse osmosis membrane that separates the salt content from a permeated solution. The concentrated solar panel system heats brackish water before it enters the reverse osmosis membranes, allowing for an increased separation rate of salt particles from purified water. This desalination system can remove about 99% of particulates per pass while using 0.63 kWh to purify each cubic meter of water. Based on Southern California Edison's rate of $0.46 per kWh, this unit saves $0.29 per cubic meter of desalinated water while, on average, producing 1 liter of permeate every 10 minutes. The Environmental Protection Agency defines potable water as having less than 500 mg/L of total dissolved solids within the solution. Assuming the salinity of brackish water is between 500 to 10,000 mg/L, this unit can produce fresh drinking water from a wide range of saline solutions of varying salt content. Sodium chloride has been the target solute to remove due to its majority presence in water resources around southern California, specifically in local inland aquifers. In conclusion, this desalination system can remove sodium chloride from brackish water and effectively produce potable water while solely using renewable energy to power each process.

Analysis of National Bridge Inventory Data for California Bridges

Emily Yu, Rosa Vasconez | California State Polytechnic University, Pomona

Abstract

The National Bridge Inventory (NBI), managed by the Federal Highway Administration (FHWA), is an untapped source of data that accounts for all bridges and tunnels that are more than 20 feet in length within the United States. It records significant data regarding bridge properties which include: roadway classification, geographic location, age, material, structure type and others. Although data has been studied briefly in some research, in depth analysis for specific states has not been performed. The objective of this research is to understand NBI data structure and its limitations; retrieve, organize, and analyze bridge data, and provide meaningful information on bridge properties and performance. This research will focus on bridges in California, with an emphasis in Southern California counties around and including Los Angeles such as Kern, Los Angeles, Orange, Riverside, San Bernardino, San Diego, and Ventura counties. Trends and correlations will be drawn from data analysis and statistical comparisons. It is expected that a correlation between bridge performance and its properties will be established. Relationships between bridge performance in California in terms of strength and serviceability will also be examined. The data for analysis is provided by NBI, which is available through the FHWA website, the National Bridges website, which is an online database search engine that is based on data from the NBI and information from the Department of Transportation for each state, and the Department of Transportation website.

Enhancing Public Awareness of Engineering Profession via Strategic Partnerships

Manoochehr Zoghi | California State University, Fresno

Abstract

In a report entitled: "*Moving Forward to Improve Engineering Education*," published recently by the National Science Board, three key challenges have been identified in engineering education. One of these key challenges is responding to the changing global context of engineering. The rapid changes of global economy are impacting the engineering profession and supply chains have become a great deal more international. It is reported that the conventional basic engineering skills have become commodities that many other countries can provide at a lower cost. As a result, U.S. engineers must possess new skill sets beyond the conventional ones. The second key challenge is in relation to the student success. It is well known that there is a substantial attrition in engineering. This is especially acute for the underrepresented and minority students. The graduation rate of first time freshmen is merely 60% nationally. There have been various initiatives launched in the recent past to address this challenge. An important factor has been the lack of belonging during the first one or two years of college. Considering that the majority of courses engineering students take in the first few semesters are primarily in science and general education, taught by nonengineering faculty, students don't have a sense of belonging to their chosen program of study. The third and final key challenge, identified by the National Science Board, is perceptions of engineering. It is believed that the society in general does not have an accurate perception of engineering profession. In addition, the field of engineering is not attractive to some, while it is intimidating to others – especially to underrepresented and female students. Female students have the perception that engineering is a male dominated profession and they are incapable of handling the rigor. The intent of the proposed paper is to further elaborate on the preceding interrelated key challenges – with the primary focus on the public perception and how to enhance the public awareness about the engineering profession via strategic partnerships. It is important to establish close partnership with the K-12 and community colleges at the front end of undergraduate engineering education and to develop strong relationship with the industry at the back end. These strategic partnerships will provide career pathways and will make students' education more relevant. Examples and assessments of these partnerships will be presented in the full paper.

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Enhancing Public Awareness of the Engineering Profession, provides an excellent opportunity to present and share innovative approaches, tools, pedagogies, and best practices for addressing the challenges of creating greater understanding of engineering in the general public. Particular emphasis will be on student outreach, recruitment, retention, and other success strategies that increase participation among a broader cross-section of community members, tied to improving the 4- and 6-year graduation rates, and reduce the achievement gap for historically under-represented minority, low-income, first-generation, and women students.

PARTICIPATION

We welcome participation of educators from all engineering, technology, and STEM disciplines. We encourage participation of educators and professionals from universities, community colleges, K-12 schools, industry/corporate partners, and college students.

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ASEE Pacific Southwest (PSW) was founded in 1932. A multidisciplinary organization—with over 1,100 members from institutions in Arizona, California, Hawaii, and Nevada—PSW welcomes all STEM disciplines.

The California State University

Course Redesign with Technology Initiative

Redesigning Bottleneck Engineering Courses

Angela Shih, Ph.D.,
Professor and Chair
Mechanical Engineering Department
Cal Poly Pomona

Leslie Kennedy
Director, Affordable Learning Solutions
California State University
Office of the Chancellor

Cal Poly Pomona (CPP) has one of the largest engineering programs in the US with over 5,500 undergraduate students. Engineering education is under considerable pressure to include more and new materials, to restructure the course content using new approaches and technologies and to manage a spectrum of students with diverse backgrounds in spite of the reduced total number of credits for graduation. Most engineering curricula have become more intensive and thus students are required to spend more time for each subject. With limited financial support, an increasing number of students at CPP are working during the week. A heavy working schedule limits the students' ability to take classes in certain days and times, and impedes the students' ability to seek help during regular school hours. These factors attribute to a high number of students retaking certain bottleneck courses, preventing the students to move forward in their study plan and delays their graduation time. To combat the enrollment bottlenecks, the CSU Office of the Chancellor is supporting an array of programs to improve students' learning success through course redesign that responds to local campus needs.

Since 2013, the Mechanical Engineering Department at Cal Poly Pomona has won a number of Course Redesign with Technology grants. Faculty members in the ME department working in teams created hundreds of micro-lectures in video format, together with other educational technologies such as iclickers, smart-books and online concept problems to redesign six bottleneck courses in Statics, Dynamics, Strength of Materials, Fluids, Thermodynamics and System Dynamics. The videos include lecture series by experienced senior ME faculty, demonstrations, simulations, derivations and homework examples. The videos are organized in ME's own website: www.cpp.edu/~meonline.

Welcome to Mechanical Engineering Online!

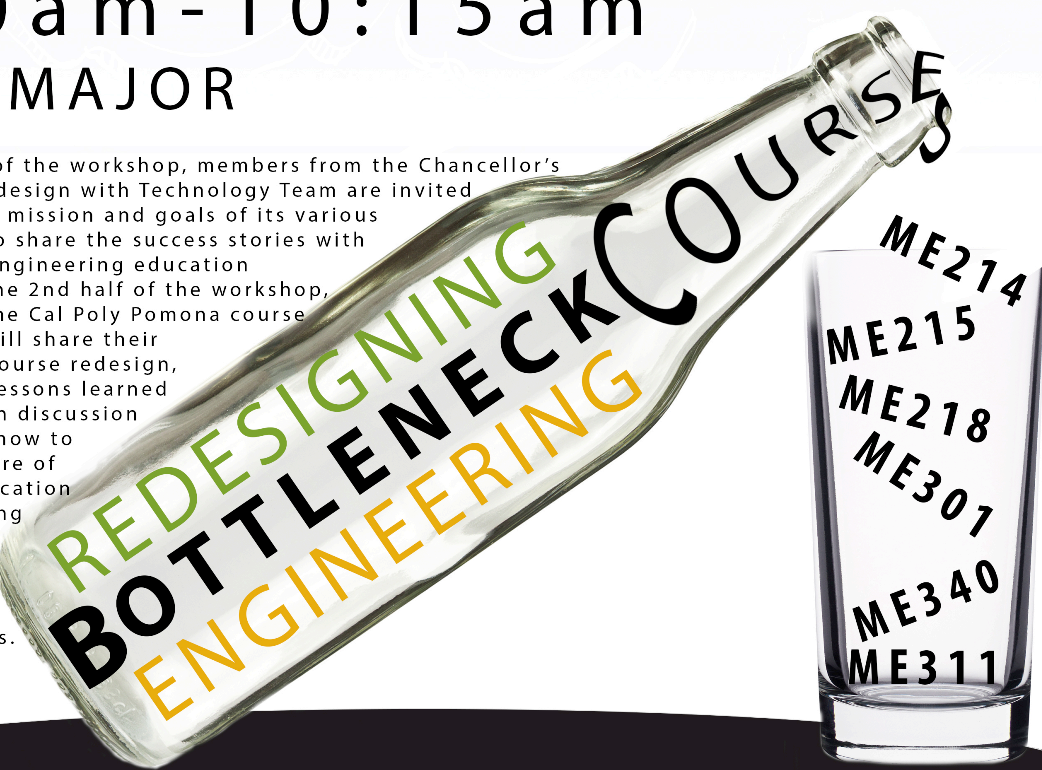
2016 ASEE PSW Conference Sponsor

Friday, April 22, 2016

9:00am-10:15am

URSA MAJOR

In the first half of the workshop, members from the Chancellor's Office Course Redesign with Technology Team are invited to introduce the mission and goals of its various programs, and to share the success stories with the rest of the engineering education community. In the 2nd half of the workshop, members from the Cal Poly Pomona course redesign team will share their experiences in course redesign, best practices, lessons learned and lead an open discussion with regards to how to reshape the future of engineering education utilizing emerging technology to actively engage students and to improve students' success.



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COMMUNITY INVESTMENTS

According to the U.S. Bureau of Labor Statistics, the United States will have more than 1.2 million job openings in science-, technology-, engineering- and mathematics- (STEM) related occupations by 2018. Yet, there will be a significant shortage of qualified high school and college graduates to fill these careers.

As an employer constantly seeking out top-talent and as a socially responsible corporate citizen, supporting STEM education-related programs is the cornerstone of Tesoro's community investment strategy. Our investments in STEM education programs are making an impact. Here are some examples:

Tesoro Afterschool STEM Academies

Tesoro awarded $2.125 million to several Boys & Girls Clubs and YMCAs throughout greater Long Beach, California to launch innovative, afterschool STEM programs for middle school students.

Aquarium of the Pacific

To revitalize its mobile tidepool exhibit, Aquarium on Wheels, Tesoro awarded $200,000 to Aquarium of the Pacific in Long Beach, California.

FIRST Robotics

This year, Tesoro is investing $215,000 to help fund regional FIRST Robotics Competitions in areas where we operate.

CAREERS

As a fast-growing energy industry leader and Fortune 100 company, we hire exceptional people with the passion to make a difference. From engineers to pipefitters, chemists to accountants, IT specialists to welders, Tesoro's success relies on our ability to recruit and retain employees with exceptional STEM-related skills.

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Maximizing Engineering Potential

Center for Gender, Diversity & Student Excellence

COLLEGE OF ENGINEERING
CAL POLY POMONA

Mission Statement

The mission of MEP: Center for Gender, Diversity & Student Excellence is to prepare historically under-represented minority, women, low-income, and first-generation engineering students to become professionals and leaders capable of tackling life-long, intellectual, socio-ethical, and career challenges in a changing world.

Vision Statement

MEP: Center for Gender, Diversity & Student Excellence aspires to be a premier center of excellence for preparing diverse communities of student learners for academic, professional, and leadership opportunities in a global society.

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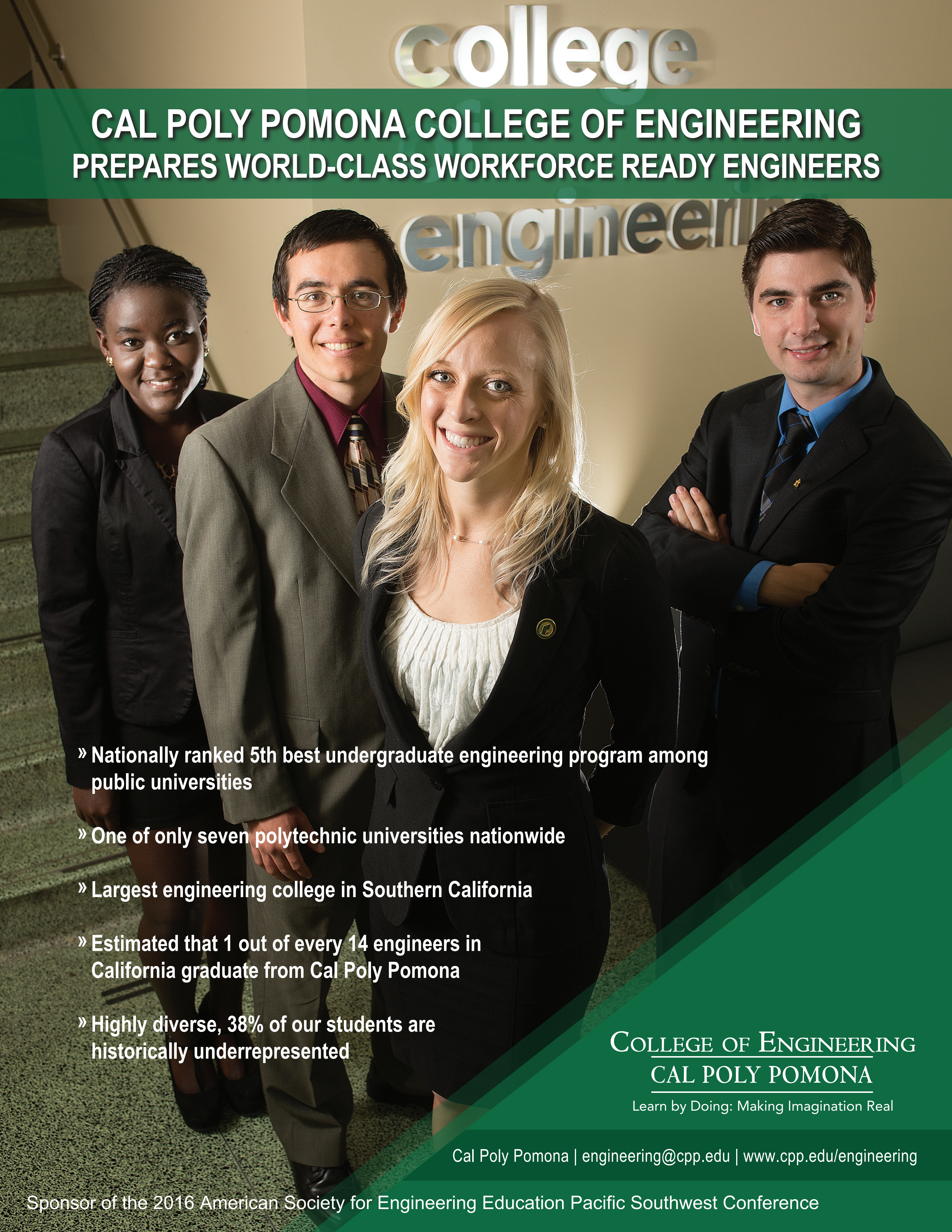
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- Providing leadership and scholarship opportunities

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