An Introductory Design and Communication Course Intended for all Engineering Majors Takes it to the Farm

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Work in Progress – An Introductory Design and Communication Course Intended for all Engineering Majors Takes it to the Farm

Introduction to Engineering Design course, or ENG 3, is a general elective hybrid communication and design class offered to all engineering students at the University of California Davis (UCD), regardless of their class standing or major. A core objective of the course is to provide vital connections between engineering content, oral communication skills and creative problem-solving through an engaging multidisciplinary team design experience without increasing time to degree.

Course structure involves a weekly large format interactive lecture session followed by a studio session where smaller groups of students participate in hands-on collaborative activities. Homework and presentation assignments are structured around a team-based engineering design project that emphasizes key stages of the engineering design process along with several forms of communication that engineers typically utilize in design.

In Fall 2017, an exploratory student team design project for ENG 3 was piloted in collaboration with the UCD Student Farm named “Physical Computing Design Solutions for Farmers.” The design project fulfilled key objectives of the course, namely to introduce the engineering design process and to provide a meaningful experience for students to develop their oral and technical communication skills. All students were provided digital technology kits for use in the project and instruction in order to create a more level-playing field for those who lacked prior experience. Through the project, students worked in collaborative teams to address an authentic open-ended on-campus challenge with broader real-world implications. Project milestones were structured around a series of formative communication assignments (e.g., a slide presentation, a videotaped elevator pitch, a technical status meeting using the whiteboard, an initial design presentation with prototypes and, a preliminary poster presentation) leading to the final poster and prototype presentation at the ENG 3 Design Showcase.

Integrated communication and engineering design topics provided a rich opportunity to explore student outcomes across a wider population of students in the college of engineering. Initial research findings from fall 2017 focused on changes in students’ self-efficacy in engineering design using a vetted pre- and post- survey instrument “Engineering Design Self Efficacy,” developed by Carberry et al (2010). Other data collection included a survey on students’ prior knowledge and skills with physical computing technology, along with a survey on students’ self-rated abilities leading up to the team assignment. Course development and the design project are discussed along with preliminary student outcomes and implications for future work.

Background

With major efforts underway to revolutionize the teaching and learning of engineering at the undergraduate level (Goldberg and Somerville, 2015; Borrego et al, 2010; NAE, 2004), academic innovations that cross boundaries of traditional course work are often necessary in order to meet vital objectives, namely to engage students, to improve diversity and to boost retention while keeping time to graduation feasible. Recommendations to teach nontechnical aspects of engineering within technical contexts while making stronger connections to practice early in the undergraduate curriculum has been supported through numerous studies (Passow and Passow, 2017).

The case for integrating oral and written communication curriculum into existing undergraduate engineering coursework is not a new idea (*see* ASEE Engineering Enhanced Liberal Arts Project) with approaches that range from writing across the curriculum, to interdisciplinary courses and integrated programs (Leydens and Schneider, 2009; Ford and Riley, 2003; Nutman, 1987). The teaching of communication skills in ways that will more effectively transfer to future workplace expectations to learners is a widely recognized objective among industry and post-secondary academic advocates (NACE).

Given that engineering design is foundational to the undergraduate educational experience, as defined by ABET outcome criteria (c) *an ability to design a system, component, or process to meet desired needs within realistic constraints* (ABET, 2017), initiatives to teach design principles prior to students' capstone experience has received considerable attention (McKenna et al, 2011; Palmer et all, 201l, Dym et al, 2005).

Engineering design and communication share essential features, particularly in terms of applied technical and nontechnical elements. Integration of these topics into undergraduate coursework offers the promise for a more relevant and authentic educational experience. Authentic learning environments are, by nature, real-world and student-centered (Strobel et al, 2017; Jonasson, 1999). Development of these curricular experiences requires an eye towards better understanding students' skills, their perceived value of the educational activities and their motivation to engage. The later has been closely associated with students' self-efficacy (Mamaril et al, 2016), or their belief in their ability to succeed (Bandura, 1997). Studies of undergraduate engineering student self-efficacy have shown positive correlations to academic achievement (Hseigh et al, 2012) and persistence (Concannon and Barrow, 2010).

This integrated communication with engineering design course development and implementation project aims to better understand students' engineering self-efficacy through the lens of a team-based real-world technical design project (i.e., physical computing design solutions for farmers).

Course Development

The Introduction to Engineering course at UC Davis was initially conceived by the Engineering Communications and Design Committee in 2013 to serve first-year students from all seven of the academic departments offering undergraduate degrees in the UCD College of Engineering (COE). A representative from each of the seven departments served on the committee. Members were from Biomedical Engineering, Mechanical and Aerospace Engineering, Chemical Engineering and Materials Science, Electrical and Computer Engineering, Computer Science, Civil and Environmental Engineering, and Biological and Agricultural Engineering. The committee identified several reasons for coupling the communication course with engineering design, namely the lack of an appropriate communication elective at the university that adequately served the engineering curriculum and the difficulty students had in taking the existing communication courses until their senior year due to impacted enrollment. Other motivations supporting the need for a hybrid communication and design course were the lack of hands-on design experiences offered early in the undergraduate curriculum along with persistent issues of retention in the COE programs. The committee identified core outcomes the course would fulfill in oral literacy and social sciences.

Oral literacy requirements:

a. Students should learn preparation, delivery, organization, listening, logic, clarity, and the rhetorical elements involved in persuasion.
b. Students should learn how to construct non-fallacious verbal arguments, recognize fallacious arguments, and be able to understand the verbal arguments of others.
c. Students should be able to communicate an understanding of pertinent issue(s) related to the course.

General Education topical breadth requirements:

a. Arts and Humanities: students should learn significant intellectual traditions, cultural achievements and historical processes.
b. Social Sciences: students should learn the individual, social, political and economic activities of people.

Course features outlined by the committee addressed how the course would satisfy and improve upon the general education core literacy area of Literacy with Words and Images – Oral Skills, and topical breadth area of Social Sciences. These features included a series of oral presentation assignments inherent to engineering: PowerPoint, Poster, chalk board/white board, panel presentations, question and answer sessions to peers, instructors and clients. The need for a design experience where students would share ideas and progress with peers and present their design solutions to a client was highlighted.

There was a consensus that the design problems should be real so as to achieve more engagement by the students and ideally with local clients and campus community on problems students could address. It was recommended that these design projects be tailored toward students with minimal training in calculus, chemistry and physics. In respect to ABET student outcome criteria, the course would prioritize (d) an ability to function on multidisciplinary teams, (g) an ability to communicate effectively, (i) a recognition of the need for, and an ability to engage in life-long learning, and (j) a knowledge of contemporary issues.

The initial offering of the ENG 3 course was to 39 students in fall 2015. During this time, the curricular materials, presentation assignments, rubrics for assessing communication skills, and a pneumatic powered robotic arm design project were piloted by co-author VanderGheynst. A summary of the course lecture plan is provided in Table 1. The course was hugely successful in terms of student engagement and viability of the learning content. Adjustments were made during winter 2017 implementation, particularly with the inclusion of two mid-term prototype testing assessments in a competition-like setting (Table 2).

Table 1. Lecture topics for ENG 3 in winter 2017

Week	Communication topics	Design topics
1	Listening skills, and individual and group values and their importance in problem solving	Engineering defined and the role of social sciences in engineering
2	Introduction to communicating as an engineer	What is design? Identifying needs
3	Working in teams	Conducting background research
4	Development of verbal arguments, elements of persuasion, an elevator pitch	Problem definition, categorize and define needs, engineering reasoning, conceptual design.
5	Creating and delivering a technical slide presentation	Product benchmarking
6	Brainstorming and technical meetings	Product definition and prototypes
7	Preparing and delivering a poster presentation	Developmental research
8	Development of verbal arguments: rhetorical elements	Prototype testing and data collection
9	Additional topics in professional communication	Social, political and economic aspects of design

Table 2. Studio activities for ENG 3 in winter 2017. Students were tasked with designing a pneumatic robot for collecting soil.

Week	Communication Activity	Design Activity
1	Listening skills	Design problem and supplies. Conservation of energy, Pascal's principle, levers
2	Review of listening skills	Introduction of client and soil. Integration of design process into design challenge. Identifying needs. Team assignments
3	Team communication strategies	First competition: base hip actuation for robot
4	Presentation 1: team presentation using PowerPoint on process demonstrated in studio 1	Sketch arm actuation for robot
5	Strategies to improve your team	Second competition: Hip + arm actuation
6	Brainstorming	Brainstorm on designs to collect soil. Use product benchmarking process.
7	Presentation 2: team presentation using PowerPoint on robot design.	Build prototype robot for collecting soil
8	Presentation 3: Technical meeting. Teams present to instructors using white boards	Sketch and assemble robot
9	Presentation 4: Practice poster presentation including pitch.	Complete and test assembled robot. Refine as necessary
10		Robot competition - use of full system

These assessments facilitated early discovery of potential pitfalls in students' designs, allowed students to recognize the value of early failure in design, and ensured steady completion of the design project over the course of the term.

Course Implementation in Fall 2017

In Fall 2017 a dedicated faculty member was recruited and assigned to lead course enhancements towards facilitating further expansion of the course. During this time the "Physical Computing Design Solutions for Farmers" design project was conceived and implemented to support the vision and objectives set by the committee. Other goals, central to the mission of the university to build a culture of inclusivity, equity and diversity were foundational in further development of the course experience.

Student Demographics

In fall 2017, forty-eight undergraduates were enrolled in the ENG 3 course. While the course was intended for first year students, given its newness, the majority of students enrolled were sophomores (54%) followed by freshman (25%), juniors (19%) and one senior. Twenty-one percent of the students were female, in contrast to the undergraduate COE student body of 29.7% female in fall 2017. ENG 3 student demographics by major are presented in Figure 1 with over 41% in Mechanical and Aerospace Engineering, 27% in Electrical and Computer Engineering, and just over 20 % in Civil Engineering. Biological Systems Engineering (6.3%) and Biomedical Engineering (4.2 %) majors were lesser represented. Students from other majors in the COE were not enrolled for a variety of known (e.g., the course was not a department approved elective or requirement for the major) and other unknown reasons (e.g., students and their advisors may have been unaware of the course, etc.).

Percentage by engineering majors in fall 2017 is provided in Figure 2 to illustrate the distribution of all undergraduate students across the COE. It is worth noting that Material Science, Chemical Engineering, and Computer Science and Biochemical Engineering together accounted for over 27% of the undergraduate engineering student body in fall 2017. None of these majors were represented in the ENG 3 fall 2017 student enrollment. This might have been due to the fact that these majors fulfill their communications requirement in other required courses.

The course instruction team included one faculty who led the instructional activities, aided by an undergraduate and a graduate student assistant who provided critical support and feedback. Twice weekly hour-long lecture sessions were attended by all students in fall 2017 (N = 48) where a variety of communication and engineering design topics were presented.

Communication-focused lectures covered, for example, active listening, developing verbal arguments, teamwork, communicating as an engineer and rhetorical elements interspersed with design specific lectures. Design topics highlighted key stages of the engineering design process such as identifying needs, background research, problem definition, brainstorming, product benchmarking, prototyping, and testing among others.

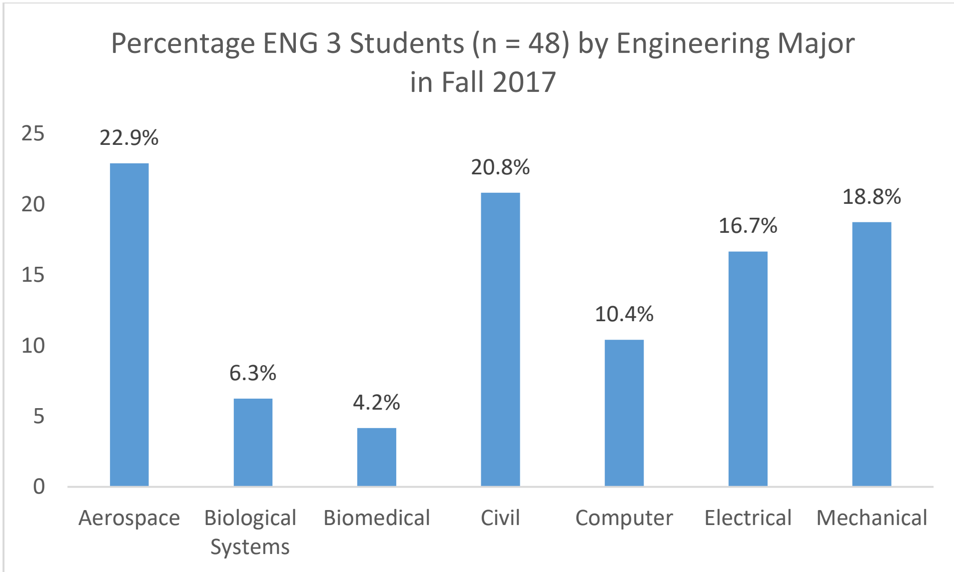

Figure 1. Percentage by engineering major of ENG 3 students enrolled in fall 2017

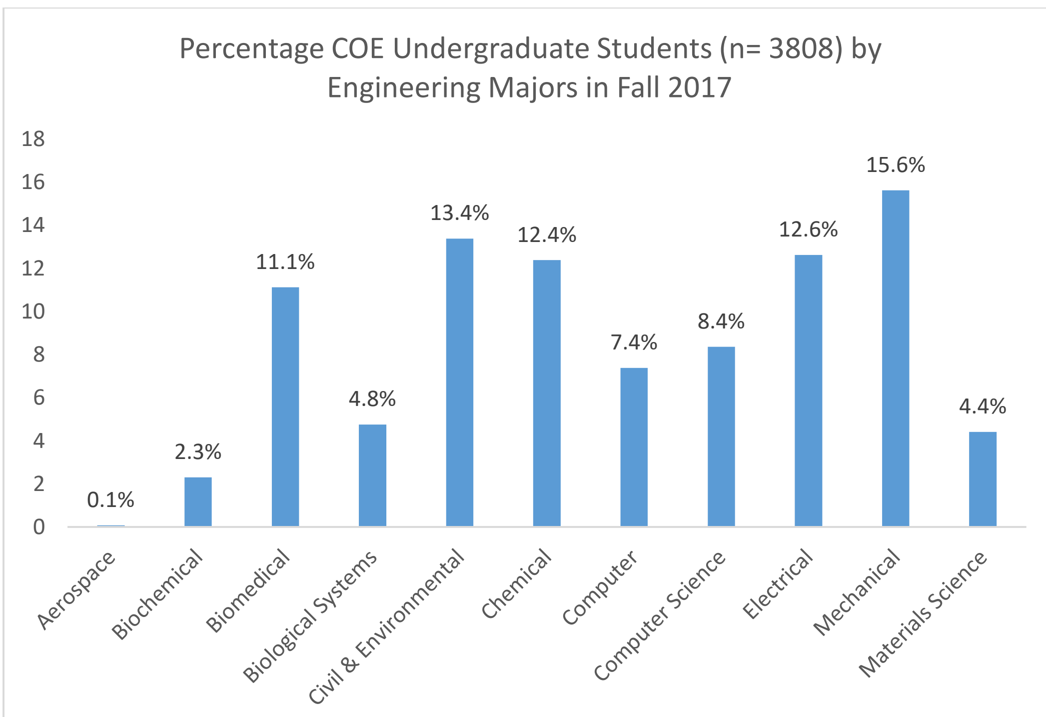

Figure 2. Percentage by major of COE undergraduate students (N = 3804) in fall 2017

Course Format

Communication and engineering design concepts were delivered through lecture in an interactive discussion format followed by in-class activities. Students were expected to attend lecture and to participate in exploration of these concepts through regularly scheduled in-class discussion, practice and reflection assignments. For example, the concept of "design problem statement" was initially introduced by the instructor in a brief lecture format followed by an in-class activity where students individually drafted a problem statement in response to Richard Turere's TED video “My invention that made peace with the lions.” Students then shared, discussed and revised their problem statements with a partner before submitting their work at the end of class. The instructor reviewed student work for misconceptions and best practices, and in a subsequent lecture used students’ work to highlight exemplars and common mistakes in writing problem statements. This lecture was followed with a graded homework assignment for students to develop a problem statement for their team’s design project. Applied practice activities, revision, reflection, oral communication and collaboration with peers was a consistent theme in lecture. Low attendance and/or participation had detrimental consequences for students as lecture activities and assignments were randomly graded. In place of a required textbook for the course, the slides were posted weekly for students to access for reference. Homework assignments, supplemental course materials and grades were delivered through the Canvas learning management system.

All students were enrolled in one of the two studio sessions offered in fall 2017. The studio sessions met once a week for 2-hours in an innovative classroom space designed specifically for the course. The room was equipped with six smartboards, projectors, moveable work benches and extensive wall space and partitions for students to write on with erasable markers. Space in the room was limited to 24 students which was essential in providing a highly collaborative hands-on learning environment for the technology activities and communication assignments that were delivered there.

In studio, all students had access to their own technology kit that included an Arduino, a Raspberry Pi, an assortment of electronic components (sensors, motors, LCD screen, etc.), a Breadboard and wires. Students were instructed on use of these technologies during the first few weeks of the quarter utilizing physical computing curriculum and technology tools developed by the UC Davis C-STEM Center. Students were introduced to coding through the C-STEM Studio learning platform with Ch, a user-friendly C/C++ interpreter, developed by the C-STEM Center for entry-level teaching and learning of computer programming. C-STEM Studio and Ch resources were accessed by the students through C-STEMbian, a free open source Linux operating system based on Raspbian, using the Raspberry Pi provided in their kit.
Teaching and student learning of the technology in studio was delivered through guided instruction led by the instructor that promoted contextualized student collaboration and communication around digital technology challenges.

For example, in the first week of Studio the instructor presented basic yet essential information on constructing simple electrical circuits using a breadboard. The presentation slides were shared with students through Canvas so they could easily follow along and review if needed. Students were then presented with a challenge task to build and test a circuit to light an LED, without explicit instructions on how to do so. Students were asked to work with others at their work station (of 4 students) to complete the task. The graduate teaching assistants provided additional support and encouragement when asked. The presentation of technical content by the instructor followed by an applied hands-on challenge task that was conducive to teamwork and technical communication was a common theme in the Studio Sessions leading up to the team-based design project.

Regularly scheduled Open Studio hours, led by the teaching assistants, were offered weekly throughout the fall quarter for students (if they desired) to meet with their teams, to work with their kits, or to get help from the teaching assistants. The open studio sessions provided additional practice for students to communicate about technical content and to actively work on their design projects.

"Physical Computing Design Solutions for Farmers" Design Project

The UC Davis Student Farm, with a perceived lack of and need for small scale technological solutions and a willingness to collaborate, presented an ideal opportunity to work with an authentic client for the ENG 3 design project. As a working year-round farm with a diversity of agriculture, on-going student-centric projects and proximity on campus, being just a short walk or bike ride from student residence halls, the farm provided a meaningful opportunity for students to openly explore, identify design needs and to develop functional prototypes with their technology kits.

The Student Farm was formed by a group of students in 1977 with the goal of learning about alternative farming and gardening through shared physical work, experimentation, and problem solving (Van Horn, 2011). Presently, the UCD Student Farm is a financially self-supporting entity led by paid staff, a director, student interns and a robust community of student volunteers (Parr and Van Horn, 2006). The farm encompasses an ecological garden, that provides education outreach, and a market garden that supports a subscription-based community service agriculture program (CSA) as well as providing produce to the campus dining facilities. Given the array of agricultural activities and active locations on the farm (e.g., greenhouse, packing shed, summer fields, winter fields, vineyard, fruit trees, nut trees, olive orchard, etc.) an informal agreement between the farm leadership and the ENG 3 instructor was reached in fall 2017 to explore the possibilities through an ENG 3 physical computing-themed design project.

The "Physical Computing Design Solutions for Farmers" design project was developed by the author to align with the pre-existing communication and design content and accompanying student communication assignments. The design project followed a seven step creative engineering design process highlighted in lecture with student design outcomes structured around key presentation assignments (i.e., the project milestones).

The general concept of the design project was introduced to students in studio during the first week of classes as a context for learning how to use the technology kits over the subsequent few weeks. Before students were given specific details about the design project or were assigned teams, they also took an on-site guided tour of the farm, in groups of approximately 18 students, that was led by the Farm Field Coordinator. During the farm tour, students were instructed to listen, to observe, to ask questions and to keep a record of problems, challenges or needs they felt could potentially be address through the team design project.

The "Physical Computing Design Solutions for Farmers" assignment was presented and discussed in detail on week 4 in the studio sessions. Teams of 3 to 4 students were assigned by the instructor based on informal observations of student interactions and students' self-reported skill sets. Students were provided a 3-page document with specific details about the team assignment, project milestones and grading criteria. The design assignment is summarized below:

> *Your team will design, test and build a device that addresses a specified need at the UC Davis Student Farm. Your device must incorporate elements of physical computing using parts from the technology kits (i.e., Raspberry Pi, Arduino, motors, sensors, etc.) provided in the ENG 3 studio. The completed device must have the following features:*
>
> - *an identifiable input and an output (at least one of each)*
> - *a functioning computer program to control the device*
> - *a well-constructed and presentable case, chassis, or structure to secure and protect the electronics.*

Project Milestones

Teams demonstrated their progress in the design project at key milestones throughout the quarter. Each milestone was accomplished by a technical presentation assignment that communicated aspects of the team's evolving design, activities and outcomes.
The presentation assignments involved a variety of presentation styles beginning with conducting a technical review meeting (Milestone 1), presenting prototypes (Milestone 2) and delivering a poster presentation (Milestone 3) leading to the Final Poster Presentation at the ENG 3 Design Showcase during finals week. Students were provided instruction and grading rubrics on each of the presentation assignments to guide their efforts.

Leading up to the design project and preceding the milestones described above, two other presentation assignments were assigned to support the physical computing and farm-themed design project. On week 3, a team slide presentation on how to use the digital technologies in the kits, Presentation #1 "Process Engineering – How To", was delivered in studio. During week 4, students submitted Presentation #2 "Elevator Pitch", an individual assignment video-taped and uploaded to Canvas where students pitched their ideas on robotic solutions for agriculture.

Design Showcase

In lieu of a final exam, the student teams presented their posters and functional prototypes during finals week at the ENG 3 Design Showcase held in the studio classroom for invited guests. Student teams arrived in business casual attire, with a presentable prototype, and projected a digital copy of their poster presentations on the Smartboards.

Stations were set-up along the perimeter of the room so guests were free to approach and interact with the teams as they preferred. Invited guests included the [University] student farm director and field coordinator, faculty, student advisors from across the COE, alumni, and representatives from other campus programs. Guests were provided a rubric and asked to evaluate the teams they met with on their engineering design, communication and presentation skills. The guest feedback was taken into consideration in determining the students' final course grade.

Students' final projects addressed a handful of problems that were identified during the farm tour. Examples of the student inspired design solutions included soil moisture sensor and irrigation systems, rodent detector and repellant systems, temperature and UV alert systems, and a digital crop status system to replace the farm's erasable whiteboard method.

Results

Given the newness of the design project and overarching goal of growing the course, an educational research plan was initiated during fall 2017 in order to better understand the students' educational needs and interests around the communication and design objectives. Data collection included two instructor-developed surveys, one to determine the students' in-coming technology skills and prior experience working with a design team. The other instructor-developed survey asked students to self-rate their technology skills and to share particular problems on the farm they found interesting to help with the team assignments.

Students were invited to take the Engineering Design Self-Efficacy (EDSE) instrument, a 36-item instrument designed to measure individuals' self-concepts toward engineering design tasks. The instrument was used as a pre- and post-test, and delivered on-line, to learn more about impact of the Physical Computing for Farmers project on students' design skills in terms of their self-rated confidence, motivation, ability to be successful and general anxiety in carrying out a series of engineering design tasks. Given the focus of the ENG 3 course and exploratory nature of the project, analysis of student data focused on a subset of EDSE data, namely the following three engineering design tasks: "to identify a design need," "to construct a prototype," and "to communicate design."

Students' Prior Technology and Team Skills

A student survey, developed by the instructor, was given early in the quarter. Survey results revealed how little experience most students had with the Arduino, Raspberry Pi and other electronic technologies prior to beginning the course. Results of the survey indicated that relatively few of the students who completed the survey (n = 38) had experience with Arduinos or Raspberry Pi, only 11% reported using a Raspberry Pi and 18% reported using an Arduino. Students self-reported experience studying or tinkering with electronics was mixed with 55% reporting *not* having taken a course or tinkered with electronics; 84% of the students reported having either taken a programming course or having taught themselves (see Figure 3).

Results of the same survey revealed that 55% of the students had completed a design project and 84% had participated in a team-based design project.

Before the design teams were assigned, students were asked to complete an on-line survey that included items on their self-assessed project-relevant design skills and what types of problems they were interested in working on. The follow-up survey developed by the instructor was administered to all students in week 3 following the farm tour. Students were asked to rate their skills on a series of project-related activities (e.g., project management, knowledge of farming, constructing a prototype, etc.) and to share project ideas that interested them on an open-response item. Survey results indicated that several of the students felt most competent in their project management and data analysis skills, the vast majority knew little about agriculture or farming, and few felt competent in their abilities to build and test electronic circuits, or building or testing prototypes (Figure 4).

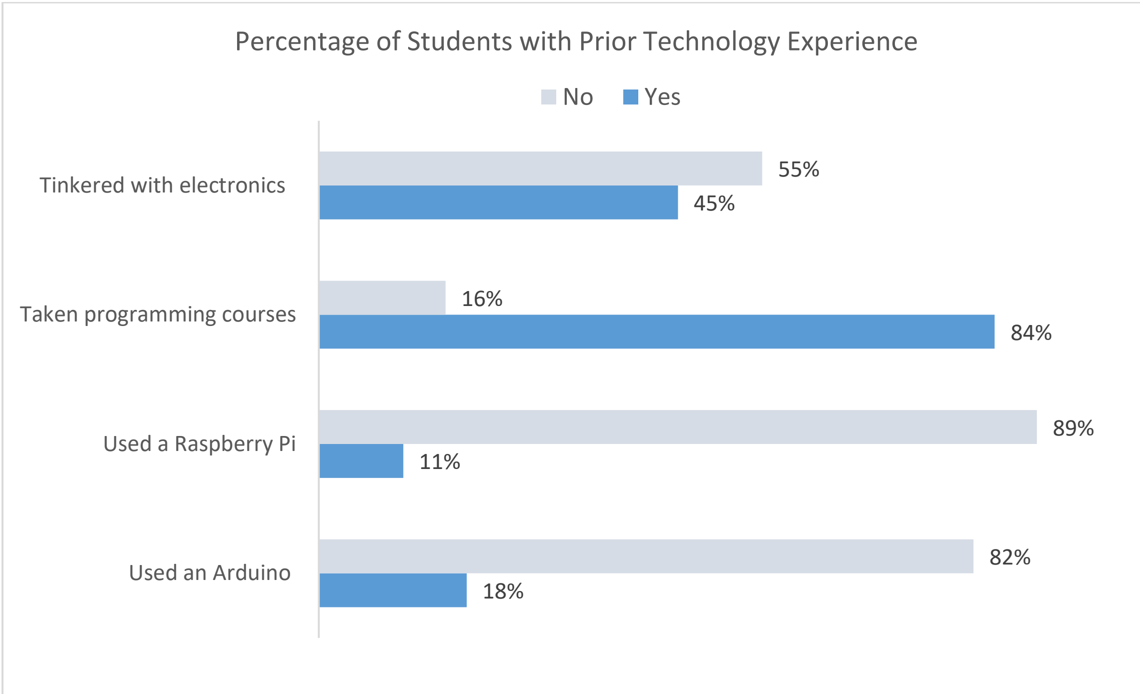

Figure 3. Percentage of students (n = 38) with prior technology experience in fall 2017

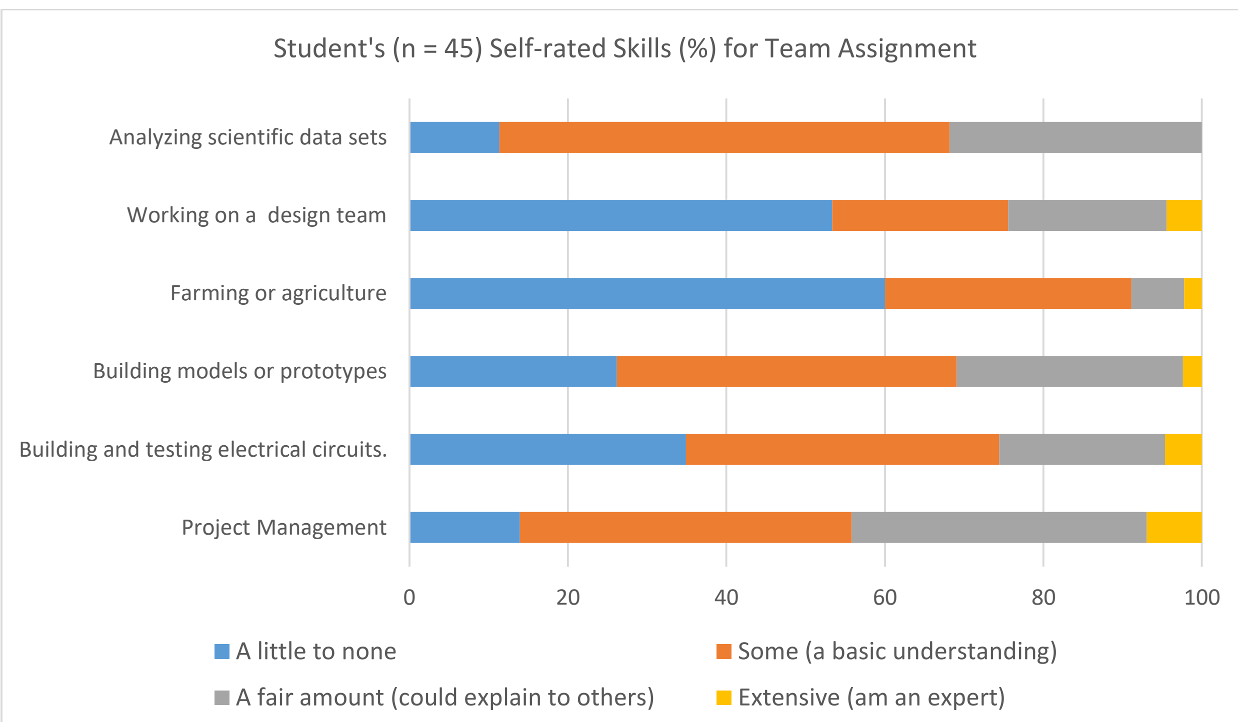

Figure 4. Results of students' (n = 45) self-assessed project-related design skills prior to the team project.

Despite having reported on the first survey about having design team experiences (84%), only 24% of the students reported having a fair amount or extensive skills in “working on a design team.” Interestingly, 26% of the students reported their “building and testing electrical circuit skills as either fair or extensive. Overall survey results indicated that students rated their skill set highest in Project Management (44 %) either fair or extensive, and “building models or prototypes” where 31% rated themselves as either fair or extensive.

Students (n = 45) provided a first glimpse into issues on the farm they were interested in working on in the open-response survey item “Share some of the needs or problems on the farm you are most interested in working on.” Among the most popular topics were irrigation systems (mentioned 24 times):

> *Water issues (monitoring, measuring, automatic control)*
>
> *Developing something that can signal when certain plants need to be watered.*
>
> *I am interested in the problem with the sprinkler system, but I also find the rest of the issues interesting as well.*
>
> *Pipe leaks (if there are no means to fix them, then adding sensors to know where they are and being able to transport the water that's leaking to other crops)*

The farm communication and organizational systems, that were mainly conducted via erasable white boards, were also of great interest (n = 15) as were problems associated with the green house (n = 15).

> *The very messy and unorganized white boards in the packaging center.*
>
> *I am interested in working on improving an outdated way of marking which crops were harvested on the white board.*
>
> *Fulfilling orders more efficiently (electronic interface to know what's been completed or what products still need to be packaged)*
>
> *Making the whiteboard system in the shed more practical (maybe having colored LED lights to show which crops are in season, etc.)*
>
> *I am most interested in the humidity/ temperature regulation in the greenhouse*
>
> *Controlling temperature/humidity in the greenhouse. Controlling and operating the watering systems that are currently being done by hand.*
>
> *Swamp Cooler/Greenhouse ventilation*
>
> *Improving air circulation in the greenhouse*

Several students also showed an interest in issues related to pest control, mentioned 10 times.

> *Some of the things I would most like to work on would be pest control.*
>
> *I am interested in anything, frankly, but the issue with the symphylans seems to be the most destructive problem at the moment, so that would be a good problem to solve first.*
>
> *Preventing rodents/animals from destroying crops.*

Other issues also mentioned including power systems, mentioned 4 times, and sunburned plants.

Lack of power in the first part of the farm as well as improvement of the greenhouse.

(AC/DC issues)

Solenoid power at eco garden

To control the amount of sun that hits certain produce so that they don't sunburn

Students Engineering Design Self-efficacy

The instructional team was interested in learning more about the development of students' design and communication skills. Of particular interest was knowing if students' participation in the design experience, from touring the farm to the final poster and prototype presentation had a measurable effect on their self-concept and abilities.

To assess changes in students' self-perception before starting the design project and at the end of the quarter, the Engineering Design Self-Efficacy instrument (EDSE), developed by Carberry et al., was utilized. Students were invited to take the 36-item survey, administered on-line, in week 2 and again in the final week of the course. Out of the 48 students enrolled in the class in fall 2017, 38 students completed the pre-survey and 45 students completed the post-survey.

The EDSE instrument Self-efficacy prompts a user to rate, on a scale from 1 to 10 (with 1 being low) their confidence, ability to be successful, motivation and anxiety in carrying out eight general but ubiquitous tasks inherent to engineering design. These tasks are: (1) identify a design need, (ii) research a design need, (iii) develop design solutions, (iv) select the best possible design, (v) construct a prototype, (vi) evaluate and test a design, (vii) communicate a design, and (viii) redesign. Self-efficacy is broadly defined by Bandura as "an individuals' judgment of their capability to organize and execute courses of action for a given task."

Given the communication focus of the course, the open-ended nature of the project and emphasis on use of digital technology in the prototypes, analysis of student EDSE pre- and post-test data focused on a subset of EDSE data, namely the following three engineering design tasks: "to identify a design need," "to construct a prototype," and "to communicate design."

A paired t-test was conducted on the 38 matched pre- and post-test EDSE student data to compare student's self-reported confidence, motivation, ability and anxiety in being able to "identify a design need" two weeks before beginning the design project and in the final week of class prior to the design showcase. Means (M) and Standard deviations (SD) are presented in Table 3.

Preliminary paired one-tailed t-test analysis results indicate there was a significant difference in the scores for students' confidence to identify a design need in the pre-test ($M=68.5$, $SD=3.2$) and post-test ($M=83.2$, $SD=2.4$) conditions; $t(33) = -5.0$, $p < 0.001$. Confidence in constructing a prototype $t(33) = -2.3$, $p = 0.01$, and to communicate a design $t(33) = -3.3$, $p = 0.001$ were also significant ($p < 0.05$) (Table 4).

Table 3. Students (n = 34) paired pre- and post-test EDSE, M and SD (+/-) in fall 2017.

		identify design need	*construct a prototype*	*communicate a design*
Confidence	pre	68.5 +/- 3.2	70 +/- 3.5	72.9 +/- 3.3
	post	83.2 +/- 2.4	79.1 +/- 3.4	83.5 +/- 3.0
Motivation	pre	75.6 +/- 3.4	85 +/- 3.1	77.3 +/- 3.1
	post	81.2 +/- 2.6	82.6 +/- 2.9	82.4 +/- 2.4
Ability	pre	70 +/- 3.3	70.3 +/- 3.5	76.8 +/- 2.9
	post	83.2 +/- 2.4	80.3 +/- 3.5	83.8 +/- 2.3
Anxiety	pre	31.8 +/- 5.1	35.5 +/- 5.6	29.4 +/- 5
	post	27.9 +/- 4.8	32.3 +/- 5.3	35 +/- 5.3

Table 4. Students (n = 34) paired pre- and post-test EDSE results for one-tailed t-test, significance < 0.05, fall 2017.

	identify design need	*construct a prototype*	*communicate a design*
Confidence	t (33) = -5 p < 0.001	t (33) = -2.3 p = 0.01	t (33) = -3.3 p = 0.001
Motivation	t (33) = -1.9 p = 0.03	t (33) = 1.1 P = 0.13	t (33) = -2.2 P = 0.02
Ability	t (33) = - 4.3 p < 0.001	t (33) = -2.5 P = <0.01	t (33) = -2.6 P < 0.01
Anxiety	t (33) = 0.67 p = 0.26	t (33) = 0.52 p = 0.3	t (33) = -1.26 p = 0.1

Results indicate that growth in students' ability to be successful in all three design tasks (i.e., "to identify a design need," "to construct a prototype," and "to communicate design") was also significant ($p < 0.01$).

While significance ($p < 0.035$) in motivation "to identify a design need" and "to communicate design" was indicated, anxiety towards these tasks was not ($p > 0.05$). Furthermore, the lack of significance in motivation and anxiety for "to construct a prototype" ($p > 0.1$) deserve further attention.

Preliminary EDSE results for students' anxieties to "identify a design need," "construct a prototype," and "to communicate design" were interesting and deserving of further investigation. Although, it should be noted that the post-test (EDSE) was administered during the last week of classes, before the Draft Poster Presentation, a dress rehearsal where students prepare for the Final Presentation. That the students were feeling more anxious than confident at the time the survey was administered is not surprising.

Discussion and Future Work

Results of the instructor developed student surveys indicate that students came into the course with little prior experience or skills with the digital technologies (i.e., Raspberry Pi, Arduino) or knowledge of farming. While most students appeared to have prior experience as a member of a design team, few saw themselves as competent in this area. Given the emphasis on oral communication, collaboration, digital technologies and the design project it was encouraging that students from the different majors and class standings in the COE had common "room to grow" in these areas.

Also encouraging were the EDSE results in terms of students' confidence and ability to "identify a design need," to "construct a prototype," and most importantly for this course "to communicate design." Students' learning of the digital technologies was very engaging and appeared to be highly valued by the students but the preliminary EDSE results are inconclusive for motivation, and anxiety in constructing a prototype raises concerns.

Outcomes of the ENG 3 and Physical Computing for Farmers design project were encouraging and highlight areas requiring attention. For example, although all teams constructed functional prototypes and it appeared that focus on the final artifact seemed to drive team motivation, little was captured in regards to student's technical problem-solving processes or their understanding of the engineering design process. Outside of informal observation, it would have been worthwhile to know more definitively how students approached the problem along with areas where students may have needed instructional interventions.

Preliminary data and analysis of student's engineering design self-efficacy provide a starting point for improved teaching and learning of engineering design. Identifying instructional elements that contribute to significant gains in students' design self-efficacy are in order as are identifying gaps that require further curriculum development. The preliminary analysis of the EDSE data focused on three specific design tasks (i.e., identify a design need, construct a prototype and, communicate a design). Other elements of the EDSE (e.g., conduct engineering design; research a design need; develop design solutions; select the best possible design; evaluate and test a design; and, redesign) also deserve attention and analysis to inform on-going curriculum initiatives.

Although alignment between Studio and Lecture activities were in place, knowing more about student experiences, perceptions and valuation of the various components and integration approach in general would be valuable towards informed integration efforts. Anonymous student feedback collected twice in lecture (mid-quarter and in the final week) indicated that students found the design, technology and communication skills relevant and useful. Although students reported appreciating the interactive nature of the lectures, their feedback indicated a perceived disconnect between studio and lecture activities.

Conclusion

The pilot "Physical Computing Design Solutions for Farmers" team-based design project provided an interesting unifying context for students to develop their communication and engineering design skills in the integrated course. While a substantial percentage of the students came into the course with little experience working with electronics, working on a design team or knowledge of farming, the experience led to encouraging outcomes including high levels of student engagement and gains in their engineering design self-efficacy. Having a "client" on campus (i.e., the student farm) with a rich set of problems to solve and access to the site provided students with an authentic opportunity to explore, collaborate and develop their design solutions.

Preliminary course outcomes including significant gains in students' design self-efficacy highlight the potential for integrated communication and design course(s) in undergraduate engineering curriculum across engineering majors and years. Plans are underway to continue with the project through the Winter and Spring quarters, to assess feasibility for a larger student enrollment while instructional methods continue to be articulated and improved through on-going educational research.

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