Improving Multidisciplinary Understanding Through Interdisciplinary Project-based Learning in a First-Year Orientation Course

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***Abstract*—This is an Innovate Practice Full Paper. Creating modern systems with tightly integrated sub-systems relies heavily on multidisciplinary cooperation. Establishing an early value for other areas of expertise is crucial to encouraging later collaborations. This paper discusses a new first-term orientation course in Electrical and Computer Engineering at Oregon State University that is primarily taken by students pursuing a degree in Electrical and Computer Engineering. This course emphasizes collaboration and the importance of a multidisciplinary approach in engineering. The 10-week course contains engineering skills, tools, and concepts from three disciplines of engineering: Computer Science, Electrical & Computer Engineering, and Mechanical Engineering. Materials focus on how each discipline supports the other disciplines in modern engineering. Students attend one, one-hour lecture and two, two-hour labs per week. The lecture covers general engineering concepts including engineering process, design, and tools/skills. Student engineers work in teams of three, with each student focusing on a different engineering discipline. Teams design, implement, and improve on a competitive robotic project. Assessment using student surveys shows a 13% higher self-reported ability to recognize and avoid personal and engineering discipline bias from students enrolled in the new course when compared to students in the traditional course. This higher assessment value has a confidence interval of p=.005 using a two-tail T-test. Using student surveys and assignments, additional preliminary improvements were seen in student's ability to identify the need of another engineer/engineering profession to complete a portion of a project and understanding of other majors.**

Keywords—lab, first year, multidisciplinary, self-efficacy, interdisciplinary, collaborative

I. Introduction

Building on existing elements of Platforms for Learning™ [1] in the School of Electrical Engineering and Computer Science (EECS) at Oregon State University (OSU), in the fall of 2019, the First-Year Orientation 1 course was redeveloped to increase multidisciplinary opportunities and to include dedicated content on collaboration across discipline boundaries. These revisions were instigated in part by OSU's intention to make significant changes to the first-year course work beginning in the Fall of 2021. The traditional First-Year Orientation 1 course includes both lab and lecture material. The new course also contains lab and lecture material but increases the amount of lab content and number of contact hours. The new course has dedicated material focusing on multidisciplinary topics and understanding. To evaluate the new course, quantitative and qualitative assessment methods were used with the traditional course as a control for the evaluation. This paper concludes with results and recommendations for future inclusion of multidisciplinary material in first-year courses.

II. Background

To better understand the development of the new version of the First-Year Orientation 1 course, this section details important existing programs and motivations that impacted the redevelopment.

A. Need for Multidisciplinary Learning

Engineering fields utilize interdisciplinary work groups to make product creation efficient [2]. However, many engineers are unable to grasp the concepts of other disciplines due to a lack of exposure to other engineering disciplines in their education. For example, researchers at the University of Bologna discovered that a multidisciplinary approach was needed to transform a city into a smart city. Partner projects were implemented across departments and across industry partners, and the need for multidisciplinary cooperation and collaboration was crucial to the success of those projects [2].

Multidisciplinary learning involves students learning about multiple disciplines in some field. For example, a student taking a course where they learn about both Mechanical Engineering and Electrical Engineering concepts. Interdisciplinary learning is when students from multiple disciplines come together to learn one subject, such as a cross listed course that has students enrolled in an Electrical Engineering program and Mechanical Engineering Program.

Many schools provide interdisciplinary work groups in the form of senior project/design courses or research groups. Utilizing these interdisciplinary groups can boost the efficiency of the project, expand the knowledge of the participants, and increase soft skills such as communication and professionalism [2][3]. However, in these interdisciplinary work groups, complications can arise. For example, students may focus on only their portion of the project and are unhelpful to others, the group might be missing a representative/knowledge from a discipline that is crucial to the success of the project, or participants have issues seeing the problem from another discipline's perspective [4]. Multidisciplinary learning gives engineering students a base knowledge of other fields to help them be more prepared for interdisciplinary projects. Exposing students to other disciplines can spark interest in other areas of engineering allowing a student to broaden their skills set and overall engineering knowledge [5]. It gives them a different lens to see a project through and provides a more diverse set of problem-solving tools [6]. It also encourages students to learn from each other, since many students have different backgrounds and experiences, and this collaboration benefits their learning process [7].

B. Platforms for Learning

The School of Electrical Engineering and Computer Science at Oregon State University first presented the Platforms for Learning™ (PFL) concept in 2002 [1][8]. A PFL is an experience or object that links different classes in a curriculum. Examples could include a business plan that is built-in to multiple courses or a set of software applications that students use in multiple courses.

Key attributes of any successful PFL include personal ownership, hands-on/active learning, context, curriculum continuity, and a fun factor, as seen in Fig. 1. These attributes are central to course redesign within the curriculum especially for courses with associated lab content.

- Personal ownership of the platform is important to engaging the user's psychological ownership of the platform and its qualities. With the sense of ownership, the user will feel an enhanced sense of self-determination and responsibility related to the platform and there by the learning it embodies.
- Hands-on/Active learning has been found to help cement knowledge in a learner's mind. Learning pyramid (or Learning Cone) models traditionally hold that participation in hands-on workshops or experiences is important to increase content recall.
- Context and Curriculum Continuity are tied to modern cognitive neuroscience research in how learning is more effective when the mind is already primed to learn each item but having a place ready for the information to be stored [9]. Contextual learning within each course helps to ensure supported learning while continuity ensures that information is addressed multiple times within a curriculum.
- Ensuring that the platform experiences cause some enjoyment (fun factor) for students is important to incentivize the activities. The more time a student spends on an activity the more likely a deeper learning will occur.

The PFL developed in 2002 was a basic robot referred to as the TekBot [1]. The TekBot is an autonomous, battery powered robot that initially utilizes two push button switches known as bumpers to navigate around objects or walls. The initial TekBot will drive forward, if the robot comes in to contact with a wall or object hitting one or both bumpers it will back up, turn away from the object, and continue forward. The TekBot had a modular design, utilizing an analog controller board, a motor controller board, a charging board, and a prototyping board. The modular design allows students to incorporate new sensors, hardware, and software in later courses as they progress through their curriculum [1].

Other schools have adopted similar techniques as the PFL developed by OSU. The University of Washington created a first-year design course centered around signal-processing and the MATLAB software [10]. As stated in their work, it is common to use a robotics project or a development board to tie the introductory course and lab to other courses later in the curriculum, but they used software as their linking factor. Their choice of a program that is commonly used in upper division courses, research, and industry expands the idea of "linking" that is a key goal of a PFL. George Fox University created a "platform for education" named the MatBot based from OSU's TekBot PFL [11]. Much like the TekBot the MatBot uses a modular like design to allow the swapping of pieces as the student's knowledge base grows, however a key difference is the integration of MatLab. The MatBot is autonomously coded and controlled via MATLAB.

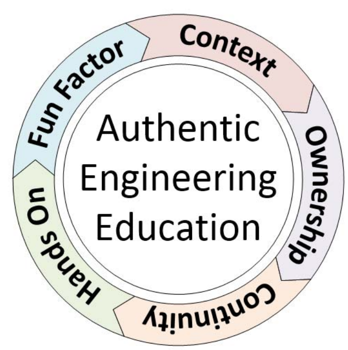

Fig. 1. Key Attributes of a Platform for Learning

C. First-Year Engineering Experience Model

The College of Engineering, which the ECE degree is a part of, is redesigning the first-year experience for all engineering majors to allow first-year students to explore many majors and reduce the amount of switching between majors. This new yearlong experience is called Engineering+ and is intended to be college wide in the Fall of 2021. Engineering+ will include the addition of Friday seminars (Engineering Fridays) and a living/learning community, limited course section sizes, unified course learning outcomes across all majors, and transition to a 2+1 model with two one-hour lectures and one two-hour studio for all required engineering courses in the first year.

D. First-Year Orientation 1 Traditional Format

An existing First-Year Orientation 1 course, "Introduction to ECE Tools," was last developed in 2015 and is traditionally taken as the first Electrical and Computer Engineering (ECE) course by students majoring in ECE. As the first course students take in ECE, the course serves to orient students to the field of ECE with some hands-on lab components. The lecture includes guest speakers from industry and academia covering broad topic areas. The lab component familiarizes students with ARM microcontrollers, how to program them, and includes 5 lab experiments tied to the subdivisions of OSU's ECE program: Computer Engineering & Networks, Energy, Integrated Circuits, Materials & Devices, Robotics, Signals & Systems, and Communication. This course is formatted as a three-credit course with two hours of lecture and two hours of lab each week.

III. New Course

The redeveloped First-Year Orientation 1 course is split into one, one-hour lecture and two, two-hour collaborative labs per week. The first offering of the course had 70 students in a single lecture and three lab sessions of 21-24 students. The course is designed to focus on collaborative learning and multidisciplinary concepts while continuing to incorporate the key attributes of a PFL.

To address multidisciplinary concepts, a variety of engineering disciplines are taught in the lecture portion of the class. The lab portion focuses on three of those disciplines: Electrical & Computer Engineering (ECE), Computer Science (CS), and Mechanical Engineering (ME). Every student must complete skill tutorials in each of the three focus fields. Not only does this allow everyone to have the same starting point, but it encourages every student to try skills in each discipline. Later in the term, the students do a collaborative robotics project (the TekBot) that involves skills and concepts from ECE, CS, and ME to be completed. The skills needed to complete the TekBot are individually addressed in the tutorials of the course so that students can focus on collaboration and problem solving together during the project not on developing the basic technical skills.

A. Lecture

Table 1 shows the timeline for the lecture topics in the course. The intentional design of the lecture is to explore other engineering disciplines. This is done by bringing in guest speakers, exploring different curricula, identifying key skills, and looking at potential companies. Students explore aspects of different engineering fields, what kinds of jobs they work, where they work, and what kinds of classes are taken.

The ordering of the major descriptions was chosen specifically to help students understand how their work in the lab portion of the course is tied to the specific discipline. The primary majors used in the lab were discussed early in lecture, which included Electrical Engineering, Computer Science, and Mechanical Engineering. Presenting lab material in context with aligned lecture presentations is a key attribute of a PFL. For example, when Mechanical engineering is featured in lecture during week 3, the following week's lab presentation reinforces the lecture. Similarly, dedicated lecture time on Engineering Communications is aligned withwhen students are forming their final groups for the TekBot project.

TABLE I. Lecture Topics by Course Week

Week	Lecture Topic
1	Introduction to Engineering
2	Visit from Engineering Advising Civil Engineering and Construction
3	Visit from InnovationX (An Entrepreneur Outreach Program) Mechanical, Industrial, and Manufacturing Engineering
4	Visit from Micron Technology, Inc. Electrical Engineering and Computer Science
5	Engineering Communication
6	Midterm
7	(No Lecture)
8	Chemical, Biological, and Environmental Engineering
9	Holiday (No Lecture)
10	Nuclear Engineering

Each week, a new engineering discipline is explored. Each discipline is introduced with a fact slide about that program at OSU.This gives students an idea of what that program entails and insight into other departments. Next, students explore the curriculum of each program, and during this time, key concepts, strengths, themes, and skills are highlighted to better understand what someone in each program would learn. Then, example jobs and job descriptions are explained, along with the companies that hire engineers from that program. Lastly, research projects, senior final projects, and discipline affiliated clubs are presented to give students a better idea of each discipline's scope in each school.

B. Lab

Table 2 shows the sequence of topics in the lab including relevant professional and technical themes. In the first 2 weeks of the course, students work individually on tutorials and a mini-project involving programming, mechanical design, and microcontrollers. This gives every student some basic familiarity and practice in these areas. Next, students collaborate in teams of three on a mini-project creating a solar servo project during weeks 3 and 4. The remainder of the labs involve students collaborating on the electrical and mechanical design, assembly, and programming of a single robot that students enter into two different competitions in weeks 7 and 10. This component of the lab gives a real opportunity to practice group collaboration and leadership skills.

The tutorial weeks 1 and 2 in the lab have each student individually responsible for doing a small mechanical design using a CAD tool, programming an embedded microcontroller to perform a specific function, and to assemble and test a basic motor controller circuit on a breadboard. Having each student do this on their own helps to prepare students for the later more advanced projects, which is an example of curriculum continuity from PFL theory.

The weeks 3-4 mini project is a team project where each team makes a solar servo system. The solar servo rotates a solar cell while monitoring the maximum voltage seen on the cell. The system then returns the cell orientation to the position with the highest observed voltage. This is students' first introduction to working collaboratively in this class. As such, the solar servo is designed and built into the course in such a way that a single student could complete it entirely on their own in the time provided. This targeted complexity was intended to reduce the stress that can occur in a team project when everyone must contribute fully and collaborate to succeed. The presentation portion of the labs support the project by providing just in time context.

TABLE II. LAB TOPICS BY COURSE WEEK

	Monday		Wednesday	
	Presentation	***Lab Activity***	***Presentation***	***Lab Activity***
1	Introduction Class Overview Resources	Tutorials: SolidWorks Arduino Soldering	Engineering tools/Skills	Tutorials: SolidWorks Arduino Soldering
2	Engineering Ethics	Tutorials: SolidWorks Arduino Soldering	Engineering Comm. Team skills	Tutorials: SolidWorks Arduino Soldering
3	Engineering Design (design process for servo lab)	Form Groups Start Solar Servo Project	Ohm's Law Power	Project Work Groups and Comm.
4	Mechanical Engineering Concepts	Project checkpoint (Solar Servo complete)	Computer Science Concepts	Work on Inter-disciplinary project (TekBot)
5	Team Skills (Tower Activity)	Project Work	Module Use	Project Work
6	Software Demonstration	Project Work	Understanding Industry: What skills do I need?	Project Work
7	Club Day	Competition 1	Industry Talk: Siemens	Project Improvement Work
8	MECOP talk	Project Improvement Work	Manufacturing	Project Improvement Work
9	HOLIDAY	HOLIDAY	HOLIDAY	HOLIDAY
10	Other Engineering Fields	Competition 2	Other Engineering Fields	Reflection and wrap-up

Weeks 5-10 lab activities focus on students working on the TekBot final project to allow for a sizable project experience. For the project, students need to design, build, and evaluate a small robotic platform, with design aspects from mechanical engineering, electrical engineering, and computer science. The robots are designed using 3D printing and laser cutting for the mechanics, and they contain embedded microcontrollers, a choice of sensors for the electronics, and open-ended programming code. This freedom in design allows for personalization by each team aiding in a sense of ownership for the work, which is a key attribute of PFL.

To promote reliance on teammates, the complexity of the TekBot project was chosen so that a single person could not complete it in the lab time provided. To keep this in context, the lab presentations at the start of this project help students to understand team dynamics and best practices. At the beginning of the project each team member chooses a discipline that they will lead the work in. Having a portion of the project to focus on gives students a purpose on their project and a sense of ownership/dedication to their role. Collaboration and group problem solving is key to make all parts of the project successfully work together.

Each team's robot enters two competitions consisting of three trials: 1) a timed navigation through a maze, 2) a quality/judging check, and 3) a basic motor control line test. To be successful in the competitions, the teams need to rely on each other and their skills. The three trials were chosen to allow projects at all stages of completion to show their work in a fun environment that focused on current successes over deficiencies. Choosing to have two competitions gives an opportunity for teams to observe results of the first competition, make intentional changes, and observe results based on those changes during the second competition. Additionally, having two competitions gives two deadlines for students to work towards helping to motivate students to finish their project in a timely manner.

Each 2-hour lab session is accompanied with a short presentation/activity. Many of these presentations are created to link lecture and lab content, obtain important skills, and provide time for guest speakers. Throughout the course, there is time for collaboration with a few guest speakers who talk about their experiences in engineering. Each of these speakers specialized in different fields and gave the students a different perspective on engineering. In addition to the presentations, there are a few activities. One example is the spaghetti tower activity where groups need to build a spaghetti tower to hold a marshmallow with a set amount of spaghetti noodles, tape, and a time limit. This activity is used to promote group dynamics and problem solving using a low stakes challenge.

IV. METHODS

Quantitative and qualitative data was collected using surveys and assignments, respectively. The surveys assessed self-efficacy, a person's belief in their own abilities to deal with specific situations, to evaluate a student's ability to handle multidisciplinary situations. Surveys were distributed to both the new and traditional courses. The assignments were created to gain qualitative data on students engineering goals, past engineering experience, and reflections of the course and their progress through it. One assignment was designed to test a student's understanding and knowledge of the other engineering fields they were learning about. All assignments were only implemented in the new course and not the traditional course.

A. Participant Selection

Two sections of the First-Year Orientation 1 were offered at OSU in Fall 2019. Students self-selected into either the traditional section or the new section of the course during their orientation week. All first-year advisors were given a description of the new course, as well as a description of what kinds of students best fit the class, and a first-year advisor suggested which section to take depending on the student's personal wants/needs for their program. Students confident that they wished to be in the ECE program were advised to enroll in the traditional course, and students who knew they wanted to be in engineering but unsure about ECE were advised to take the new course. The remainder of the students chose which section of the course to take without the assistance from an advisor.

B. Multidisciplinary Awareness Survey

The multidisciplinary awareness survey was based on material developed by M. Everett [12] and adapted to be engineering and multidisciplinary centered. Surveys were distributed in both the new and traditional courses during week 4 of the term. This is before the new course determined their final groups for the TekBot project. In the new course, surveys were distributed at the beginning of lab, and students were given 10 minutes of lab time to complete the survey. In the traditional course, the survey was distributed using an online announcement, and all enrolled students were invited to take the survey. Two announcements were made to the traditional course during week 4 of the term. The survey tool can be seen in Fig 2. In these surveys, students rate themselves from a 1 being low to a 5 being high for each prompt in the survey. The prompts on the survey were chosen because they instigate thought about multidisciplinary work groups and expand on that thought by asking students to gage their comfort on applying that multidisciplinary framework to projects.

For each item below, rate your ability from high (5) to low (1) or Unable to Rate

Perspective taking: Ability to view an engineering problem, phenomenon, or behavior from multiple perspectives
5 4 3 2 1 Unable to Rate

Integration: Ability to blend insights from different engineering perspectives to produce a more comprehensive understanding or create new meaning
5 4 3 2 1 Unable to Rate

Communicative competence: Ability to communicate effectively with individuals about different engineering disciplines
5 4 3 2 1 Unable to Rate

Holistic thinking: Ability to think about an engineering problem as part of a complex system; to apply a "big picture approach" to problem solving
5 4 3 2 1 Unable to Rate

Humility: Ability to recognize the limits of one's expertise (and the need to draw on insights from other engineering disciplines)
5 4 3 2 1 Unable to Rate

Receptive to other disciplines: Being open to information from any and all relevant engineering disciplinary perspectives
5 4 3 2 1 Unable to Rate

Willingness to collaborate (with engineering disciplinary experts and/or as part of a team)
5 4 3 2 1 Unable to Rate

Willing to achieve "adequacy" in multiple disciplines: Having a basic knowledge of relevant engineering disciplines
5 4 3 2 1 Unable to Rate

Ethical consciousness: Recognizing and avoiding personal and engineering disciplinary bias
5 4 3 2 1 Unable to Rate

Fig. 2. Multidisciplinary Awareness Survey Questions

C. Assignments

There were two new assignments designed for the new course to specifically gather information about students' multidisciplinary awareness. The first assignment was a set of reflections due at three points in the term: 1) after the tutorials, 2) after the solar servo project, and 3) after the TekBot project as part of their final report. These reflections provide data on how the projects went, how confident students felt in the course, how confident they were in their teams, and if there were any flaws in the course materials that needed to be corrected for future years. The first two reflections were distributed as a google form with prompts/questions for students to fill out. The final reflection was part of the final report, and this section of the final report was expected to be at least a paragraph of their overall experience on the TekBot project. Some suggestions were given to help the students know what to write, but they could go above and beyond those questions. This open-ended design was chosen to allow students to reflect on the TekBot project and course, instead of being tied directly to the various projects experienced in lab, like the previous reflections distributed in the google form.

The second assignment was the midterm. Questions on the course midterm were also utilized for assessment. There were three types of questions on the midterm: multiple choice, short answer, and one long answer question. Many of the multiple-choice questions tested basic skill knowledge from the tutorials and identified concepts/skills from a certain discipline. The short answer questions went more in depth in these areas asking for an explanation of a tool/skill or an example of what someone in each discipline might do. The long answer prompt from the midterm was:

> "You have a Master's in Electrical and Computer Engineering and are currently working at Tesla on their new electric autonomous car. You have been put on a committee of engineers to design, build, and test the new car. What other engineering fields are needed to complete this project? Why are they necessary? Why are you necessary?"

This prompt required students to identify other disciplines, understand what they do, and apply that knowledge to a theoretical engineering situation. It also required them to define why the given discipline (ECE) is valuable and needed in the same situation.

V. Results

This section examines the results from assessment methods presented. Both quantitative and qualitative results are presented, including comparative results between the new course and the traditional course. With IRB approval, 60 students from the new class consented and 21 students from the traditional class consented to participate in the research study. Of the 60 consenting participants in the new class, all participated in the reflections and 59 took the survey,

A. Quantitative Analysis

A two-tail T-Test accounting for effect size using Hedge's g analysis was used to analyze the multidisciplinary awareness survey data for correlations. The T-Test analysis identifies results that are likely to exist based on the treatment with another student population. For this research, a confidence interval of p=.05 was chosen as our threshold for discussion and inspection. The T-Test however is not a complete view of the data, and in educational research, effect size can be used to show the strength of effect on variables that did not test positive for generalizable statistical significance. Effect size is a metric that compares the change of mean between two items moderating it by the standard deviation of the data [13]. While effect size does not show us reproducibility of an impact, it does give a metric for observed change. For this work, effect sizes of .1-.3 were considered small, medium .3-.6 as medium, and .6 and higher as large.

From the surveys, a 13% higher rating in the new class's ability to recognize and avoid personal and engineering discipline bias with a confidence interval of p=.005 using a two-tail T-test is observed. This is compared to the survey responses of the traditional course. It is interesting to note that only this item passes the significance threshold from the T-test, while the other items do not.

TABLE III. MEAN (TRADITIONAL COURSE AND NEW COURSE), P-VALUE (TWO-TAIL TEST), AND EFFECT SIZE (HEDGE'S G) PER SURVEY QUESTION.

Prompt	Trad. Mean	New Mean	P-value	Effect Size
Ability to view a engineering problem, phenomenon, or behavior from multiple perspectives	3.77	3.67	0.66	0.11
Ability to blend insights from different engineering perspectives to produce a more comprehensive understanding or create new meaning	3.34	3.61	0.31	0.29[a]
Ability to communicate effectively with individuals about different engineering disciplines	3.43	3.73	0.26	0.32[a]
Ability to think about an engineering problem as part of a complex system; to apply a "big picture approach" to problem solving	3.95	3.97	0.96	0.02
Ability to recognize the limits of one's expertise (and the need to draw on insights from other engineering disciplines)	3.95	4.12	0.52	0.19
Being open to information from any and all relevant engineering disciplinary perspectives	4.19	4.20	0.95	0.01
Willingness to collaborate (with engineering disciplinary experts and/or as part of a team)	4.48	4.42	0.80	0.07
Willing to achieve "adequacy" in multiple disciplines: Having a basic knowledge of relevant engineering disciplines	4.23	4.20	0.86	0.04
Recognizing and avoiding personal and engineering disciplinary bias	3.52	4.15	0.005	0.74[a]

a Indicates prompts that have an effect size close to 0.3 or higher when using Hedge's g analysis

Reviewing the survey results for effect size, students from the new course have a higher average for the prompts "*Ability to blend insights from different engineering perspectives to produce a more comprehensive understanding or create new meaning*" and "*Ability to communicate effectively with individuals about different engineering disciplines*" compared to the traditional course. These two prompts show a medium effect size of 0.29 and 0.32, respectively.

Further exploration needs to be completed, but these results could be related to the design of the new course's lab. In the new course, the mini-project and TekBot project asks students to pick a portion of the project to be the "expert" in, but also, it asks students to design the project as a group. This format provides opportunities where they can communicate about multiple disciplines and utilize a "big picture" approach to design. At the time the survey was given, students of the new course already participated in the solar servo mini-project, but the traditional class had focused on only ECE topics and didn't have group projects.

While only seeing a small effect size, students report an improvement in an ability to recognize the limits of one's expertise (and the need to draw on insights from other engineering disciplines). To support this claim, the following response to the long answer question on the midterm shows a student's understanding of the importance of multiple disciplines for a diverse perspective.

> *"Experts from most other engineering fields are necessary in this sort of large-scale practical project. Mechanical Engineers are necessary to ensure that all of the mechanical components are working together well. A mechanical engineer might calculate how much vibration will impact the structural integrity of the car, or how aerodynamic the vehicle is. A Computer Science expert would be necessary in building and debugging autonomous features in the car, as well as verifying that the probability of failures of any autonomous features are acceptably low. An Electrical and Computer Engineering Master would have specialized in some subdiscipline ostensibly related to some aspect of the car, but for example an ECE would be in charge of ensuring that all sensors communicate with the computer with the proper protocol. Another ECE might make sure that the power system can sufficiently manage providing power to all of the different loads on the vehicle. A civil engineer would know more about road and traffic conditions and could help inform the development of robust autonomous driving algorithms or making sensors that would be applicable in multiple countries with different transportation infrastructures. Not mentioned above, but still necessary to Tesla, chemical engineers are critical in the research, production, and manufacture of rechargeable batteries. I don't see much of a place for Nuclear Engineers, but Aerospace Engineers could work on vehicle aerodynamics, and Manufacturing Engineers would be called in after design and testing to optimize the mass production of the vehicle. In the end, any massive venture like the large-scale production of a vehicle requires collaboration between experts from multiple disciplines to make a well thought out and robust product."*

B. Qualitative Analysis

While the quantitative assessment targeted students' abilities and impressions connected only with the multidisciplinary nature of the course, the qualitative reflections assessed multidisciplinary connections, as well as connections to Platforms for Learning (PFL).

The final report reflections used a thematic-coding system to evaluate student reflection responses. 60 students provided reflections in their final report. The following codes were used to group responses seen in the reflections:

- Context – Relating experiences or skills to past experiences or skills. Identifying past experiences that that aided with tasks or experiences in the course.

- Continuity - Identifying skills or experiences from earlier in the course.
- Fun-Factor – Identification of happiness, enjoyment, or excitement from the course or experiences.
- Hands-on – Explanations or identification of hands-on work, utilized skills, or active learning.
- Ownership – Identification of any type of ownership, this could be pride in their contributions to the project or pride in their team's accomplishments.
- Teamwork – Any explanation of team dynamic, identification of teamwork qualities, or impact of teamwork on the project. (This is broken into a negative and positive code)
- Communication – Explanations of communication systems, communication platforms, or impact of communication on the project. (This is broken into a negative and positive code)

Multiple researchers coded the responses individually allowing different perspectives on the themes associated with each response. Due to the length of the reflections, many were broken down into sections, and each section was assigned a code, which allows more than one code to be associated with each reflection. All researchers' coded reflections were combined and evaluated to find trends amongst the reflection responses. Fig. 3 shows the occurrences of each code.

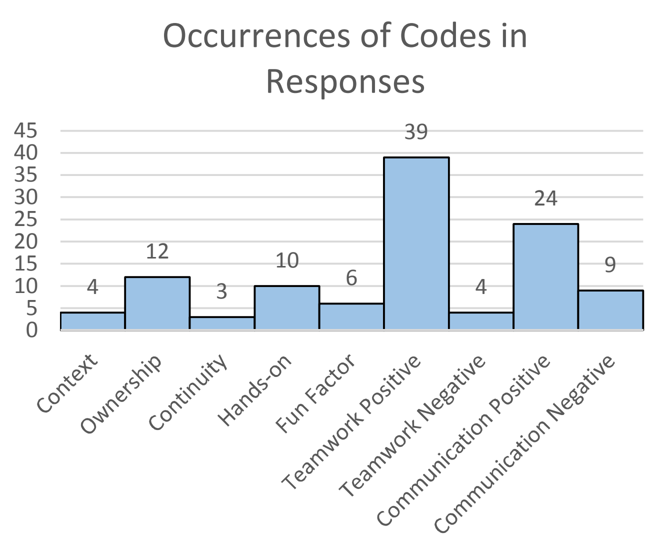

Fig. 3. Bar Graph of Occurrences of Codes in Responses

Students expressed ownership of not only their individual portions of their projects but also for what they had created with their teams, which is a key attribute of the PFL framework this course is built upon. For example, the following student, despite setbacks, indicates pride and learning from the experience.

> *"In competition 1, our bot made it a fourth of the way through the maze, got its documentation thrashed and had motor/pivoting issues. Post competition 1, we were able to clean up the errors made to improve in every section stated. The only thing our new and improved bot didn't do better in was the straight-line test. Unfortunately, the final bot didn't pass the straight-line test, but we did see improvement in all areas outside from that one negative which was very promising. I'm proud of the work we did as a group and learned more than I would have ever imagined this term."*

The course design with respect to curriculum continuity and keeping learning in context was noted by several students with how earlier work had prepared them for later parts of the course and project.

> *"Each member did a great job on their individual sections of the project. Brandon did a great job on the wiring and the diagram. He did research to make sure that each component was wired correctly and worked hard to trouble shoot when we were having problems. Allison did a great job of designing the body of the robot, and even when some of the holes were too small, she continued to work by filing the excess acrylic away. In the end, the CAD design worked perfectly. I was in charge of the code. In order to make sure everything was written correctly, I referred to our previous servo solar lab code and asked the teacher assistants lots of questions. Our code was very reliable after that research and debugging process."*

Many students reported that the course was engaging or fun with lots of opportunities for hands-on experience and practice.

> *"Overall, this lab project went very well. The material was fun and engaging while still providing our group members with enough opportunities to troubleshoot problems, building upon the skills learned in lab."*

Students comment on an understanding of the other disciplines of their project, what their team members worked on, and how they worked through their problems, even though their teammates were focusing on different disciplines than they were. Many students reported that even though they were focusing on one part of their multidisciplinary project, they helped their team in the other parts of their project as well, which allowed them to expand on their basic knowledge of the other disciplines and understand their project as a whole better.

> *"I was the least experienced in my group but, by the end of the term, I found the ways that I could be the most helpful to the project. I focused on the CAD and mounting all of the pieces. Then, when that was finished, I helped my partners wherever I could."*

> *"I do believe that although we were unable to code the robot in a way that allowed for it to solve the maze, we learned a lot about the mechanical, electrical and computer science disciplines."*

> *"Honestly, I am glad that I was forced into doing to wiring and coding because it gave me a better*

understanding of this project. I feel like I am about to use [microcontrollers] on a lot of things for my own benefits and that's the most useful knowledge I could ever ask for in this class."

The qualitative data from the various reflection assignment shows examples of students engaging in teamwork, multidisciplinary understanding, and many of the key attributes of a Platform for Learning.

C. Threats to Validity of Research

For this study, a course designed around interdisciplinary workgroups and multidisciplinary learning was implemented. This new course was compared to a traditional course that focused on only ECE topics. When analyzing a self-efficacy survey that evaluates multidisciplinary understanding, it is not unexpected to see higher values from the intentionally designed course that implements these themes into the course. In addition, this research involves a small sample size in the traditional course, which can also contribute to the threat to validity. Based on these threats, more research is needed to prove that interdisciplinary workgroups contribute to multidisciplinary learning and awareness. The results show that students in the traditional course rated their multidisciplinary abilities to be like students enrolled in the new course, regardless of not having an interdisciplinary project experience.

There was a significant difference in the material in the new course compared to the traditional course. The new course involved different lecture and lab materials, as well as introduced interdisciplinary collaborative projects. It is inconclusive if the higher ratings on the multidisciplinary survey are directly related to the implementation of an interdisciplinary project, due to the breadth of changes made to the new course.

The reflection responses have high occurrences of teamwork and communication identification but lower occurrences of the PFL themes. This could be due to the open-ended nature of the reflection prompt. The prompt asked students to reflect about their experiences with their groups, the TekBot project, and the course. Due to teams reporting about their teams many students touched on teamwork or communication in their responses. However, the reflection prompt does not explicitly call out key attributes of the PFL. This could be a partial source of the different between the two categories of responses.

VI. Conclusion and Future Work

This paper presented a redesign of an ECE First Year Orientation course to include more multidisciplinary content and enhance student's appreciation for other majors. This paper shows that the redesign increased student's opinions of their ability to recognize and avoid personal and engineering disciplinary bias. Additionally, the paper shows a medium effect size improvement for abilities to blend insights from different engineering disciplines and to communicate effectively with individuals about different engineering disciplines. Student feedback also shows strong links between the experience and the Platforms for Learning (PFL) theory. Students can explore, learn, and create projects in a collaborative multidisciplinary environment by giving them an interdisciplinary group work and communication experience.

Future work for implementing a multidisciplinary learning model is planned as the implementation of the Engineering+ experience continues. Specific items that will be included are listed below.

1. Expand the current dataset using a pre/post model of assessment. Pre and post assessments will be adopted in both the traditional and the revised course. This will allow for a richer assessment and exploration.
2. For the areas inspected in the survey, further exploration into why some areas show and impact but the others do not. This could include interviews with students to understand more clearly.
3. Encourage group dynamics and learning using low stress activities. Group work can be hard at any level so having ungraded group work can be fun and eye opening for students. Student feedback via the final reflection showed a need for stronger intergroup relationships.
4. When implementing a multidisciplinary course, reach out and collaborate with others in those disciplinary fields. This attempted as part of this development, but few guest speakers were available. For the multidisciplinary concepts to have greater effect, development/participation with experts in other fields would be needed.
5. Provide additional opportunities for students to "walk in other's shoes". This might require students to change areas of project ownership at some point during the final project.

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