Investigating Task Choice in First-Year Engineering Team Projects

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Abstract

This research paper investigates the relationship between the tasks that students take on in team projects and changes in their engineering confidence and self-efficacy during project-based learning experiences. Project-based learning has become a widely used pedagogy in engineering programs at many universities. Courses that involve a hands-on project give engineering students a “real world” experience and allow them to work in a setting that mimics a professional engineering environment: students typically work in small groups to design, build, and test while developing teamwork and communication skills. Hands-on project-based learning also provides students with opportunities to participate in solving realistic engineering problems, thereby allowing students to engage in a variety of different “mastery experiences” over the course of the semester. Beyond instilling a deeper content knowledge and aiding in the development of necessary skills, mastery experiences are one of the main contributors to self-efficacy, an individual’s belief about his/her capabilities to perform a task. Engineering confidence and self-efficacy both have important roles in a student’s ability to succeed in an engineering program, as they affect student’s decisios, motivation, retention, and career choices. However, it has been found that some students experience a negative or lack of change in engineering confidence and self-efficacy in team projects. We hypothesize that these differences may be because individuals complete different mastery experiences in team projects. The individual students’ characteristics, prior experiences, or learning goals may have a significant influence over the activities that a student chooses to take on. In this work, we investigate the different mastery experiences that students’ complete in a project and the reasons why they choose those tasks. Specifically, we are exploring the relationships between a student’s learning goals, team role, gender, time spent on various project tasks, and any subsequent changes in their engineering confidence or self-efficacy.

This study focuses on students enrolled in first-year project-based engineering courses at a large public university in the Midwestern United States. A mixed-methods approach was used for data collection and analysis. Pre- and post-course surveys were administered to collect information about student demographics and personalities and to measure the students’ engineering confidence and self-efficacy. Students were also asked to record the amount of time they spent each week on different tasks (e.g., project management, using CAD software, communication, and working on written reports) in an Activity Log. Post-course interviews were conducted to allow students to reflect about their team experiences during the semester.

Our results show that many students reported taking on certain roles because of time constraints or because they already were comfortable in that role. This could be a result of most students having performance-based learning goals and being more concerned with getting good grades in the course instead of learning new engineering-related skills. However, many students wished that they had played different roles on their teams during the semester. It seems that they

recognize taking on roles with which that they are already familiar will not increase their engineering skills and abilities during the year.

Introduction

Project-based courses have become widely used in first-year engineering courses to introduce students to authentic engineering problems while encouraging them to develop technical and professional skills. Projects can also improve students' self-efficacy by providing them with opportunities to participate in "mastery experiences." Mastery experiences in engineering are tasks that encourage students to feel that they will be more successful as engineers. Every student's experience in a project-based course is affected by the mastery experiences that they complete, which in turn affects which skills they develop and also how their engineering self-efficacy changes. A previous study focused on the mastery experiences that students took on throughout a project and their subsequent changes in engineering confidence or self-efficacy.[1–3] Here, we focus on *why* students choose to take on the tasks that they do. Three factors that may impact the project tasks that students take on are goal orientation, the roles that the student takes on or are assigned on the team, and the student's gender. These factors may affect what a student does with their time in a course and consequently can affect their engineering self-efficacy and confidence.

Background

Hands-on project design-based courses are integrated into engineering curriculum in order to give students an opportunity to apply the knowledge they have learned in a setting that mimics a professional engineering workplace. The project-based design course structure also emphasizes communication, project management, and teamwork, all of which are important skills for engineers to have for successful careers. Students participating in project-based learning are generally more motivated by their work and demonstrate better teamwork and communication skills than those who do not participate in project-based learning.[4] Projects have become popular in first-year engineering courses, introducing students to the field sooner and giving them opportunities to develop their design, problem-solving and professional skills earlier in the curriculum.[5] Projects also provide students with an opportunity to complete "mastery experiences" that could contribute positively to their expectations of success on engineering tasks, and thus improve their engineering self-confidence or self-efficacy.

Academic self-confidence, or the strength of one's belief in one's ability, is an important aspect of a student's ability to succeed in engineering courses. It has been found to be a strong predictor of student retention; self-confidence in math and science skills, in particular, have been found to correlate with student persistence.[6,7] Lack of academic self-confidence is often cited as a reason why female students leave STEM majors[8] or perceive themselves as less capable than their male peers.[9,10]

Self-efficacy, or one's perception of expected performance, is also a critical factor in a student's ability to learn engineering concepts and skills.[11,12] Self-efficacy has a significant effect on retention rates of engineering students as students with higher self-efficacy are more likely to succeed when faced with engineering challenges and to persist in the field.[6,12,13] Mastery experiences have been found to be the biggest contributor to students' self-efficacy,[14] so a students' change in self-efficacy throughout a project experience depends highly on the tasks that they complete. Students with an unsuccessful project experience, or even a successful project experience with limited opportunities to learn or transfer knowledge among team members, may not experience an increase in self-efficacy.[12] The tasks that they do take on, however, can be affected by many different factors, including the student's or the team's goal orientation[15], the role that the student assumes on the team, and the student's gender.

Goal Orientation

Students may enter projects with either a performance goal orientation or a mastery-based orientation.[16] Performance-goal-oriented students are primarily concerned with earning a good grade in the course. Students with a mastery-based-goal orientation have in interest in what they are learning and are more concerned with learning the material than they are with earning an outstanding grade in the course.

Team Roles

The role that a student takes on in their team could also have an effect on that student's engineering self-efficacy. Students may take on certain roles for a variety of potential reasons. One reason may be because the student does not want to endanger the team's success by volunteering to do something new or difficult, and thus they will default to a role that is more familiar or is perceived to be less challenging. Another reason that a student may take on a certain role is that that the student may become pigeon-holed into a certain role: if a student volunteers to write the first progress memo, for example, the other team members may expect that student will complete subsequent writing assignments, thus not leaving enough time for the student to take on other tasks. Or, another example is that there could be a student who previously had a lot of experience on a robotics team, and thus is expected by their teammates to do the wiring or coding work for the course project. This keeps that student from experiencing new types of tasks, and also keeps the other team members from trying something that is unfamiliar to them. Another reason that a student takes on a certain role could be that the role was team-appointed: the student could be assigned to a less difficult role by their teammates because the teammate is not trusted, or they could be assigned to a certain role that does not align with their learning goals because they are isolated on the team.

Whatever the reason, students who do not take on new, technically-challenging roles will not gain valuable mastery experiences and thus may not experience a great gain in engineering confidence or self-efficacy compared to their peers.

Gender

Gender-correlated assignment of roles can also occur (consciously or unconsciously) on student teams.[17] Studies have found that women on first-year engineering teams may take on clerical or organizational roles, without recognizing that they are being subject to gendered role assignment by the team.[18] Another study found that men report doing more

CAD and prototyping and women spent more time preparing presentations and learning about people's needs.[17]

Research Questions

In this work, we are studying the relationships between a student's completed tasks and changes in academic self-confidence and self-efficacy over the course of their project through the following research question:

1. Does the amount of time that students spend on certain project tasks affect their academic self-confidence and self-efficacy?

After developing an understanding of *what* students are doing in their teams, we investigated *why* students may choose to do the tasks that they do.

2. Does the goal orientation of the students affect the tasks that they choose to take on during their project?
3. Does the role that a student plays on their team affect which tasks they spend the most amount of time on over the course of the semester?
4. Do male and female students complete different tasks in their teams?

Methods

Participants and Setting

The setting of this study is a large Midwestern university. The participants in this paper were all first-year engineering students enrolled in an introductory engineering course employing a "design, build, test" hands-on team project.

Table 1 details the participants of the study. This study took place over the calendar year of 2015, during two semesters: Spring 2015 (January through April) and Fall 2015 (September through December). In the first semester of the study (Spring 2015), we surveyed students in two first-year design courses. We also surveyed students in a sophomore mechanical engineering design class, a senior capstone chemical engineering design class, and a senior capstone electrical engineering course. The main focus of this paper is on the results from the first-year courses, but some results from the sophomore and senior level courses will be mentioned briefly to contextualize our other findings. In the second semester (Fall 2015), we focused on a single first-year design course.

Table 1. Study participants.

Participation	Course	Male	Female	Unreported	Total
Spring 2015 Semester	First-Year Course 1	10	6	2	18
	First-Year Course 2	17	10	0	27
Fall 2015 Semester	First-Year Course 3	25	4	0	29
Total		52	20	2	74

Data Collection and Analysis

The students that participated in this study completed a pre- and post-project survey and weekly activity logs.

The pre-project survey was used to assess demographics, personality, their confidence in completing their degree, and their commitment to completing their degree. The students were asked to rate their engineering confidence on a Likert scale using two instruments:

1. The academic self-confidence instrument [19,20] focuses on confidence in three areas:
    a. Open-ended problem-solving
    b. Math and science skills
    c. Professional and interpersonal skills
2. The self-efficacy instrument[21] investigates students' engineering and tinkering (hands-on) self-efficacy.

The post-course survey was administered to determine if outgoing levels of academic self-confidence and self-efficacy changed from the beginning of the semester to the end of the semester.

In the weekly activity logs, the students were asked to report the amount of time that they spent on forty different project tasks. For analysis, the tasks were grouped into twelve 'activity clusters' of related tasks: Brainstorming, Calculations, Communication, Documentation, Hands-On Work, Modeling, Oral Presentation, Project Management, Research, Sketching, Teamwork and Written Report. During the second semester of data collection (Fall 2015), students also identified each week what role they played on their team.

A subset of students was asked to participate in semi-structured interviews at the end of the semester. During the interview, students were asked about why they chose engineering, how they felt their team performed during the semester, which roles they and each of their teammates played on their team, and what they learned over the course of the project.

There was a mixed-methods approach to analysis, statistically analyzing the results from the surveys and weekly logs and qualitatively analyzing the interview transcripts. Quantitative data from the surveys and weekly logs was analyzed using SigmaPlot; the specific tests done are mentioned in the results section.

Results and Discussion

Does the amount of time that students spend on certain project tasks affect their academic self-confidence and self-efficacy?

The reported proportion of time spent in each activity cluster is shown in Figure 1. The activity clusters that students reported spending the highest proportion of time on were Hands-On Work, Oral Presentations, Written Reports, and Brainstorming. The students spent the lowest proportion of time on the Modeling, Calculations, Research, and Sketching clusters.

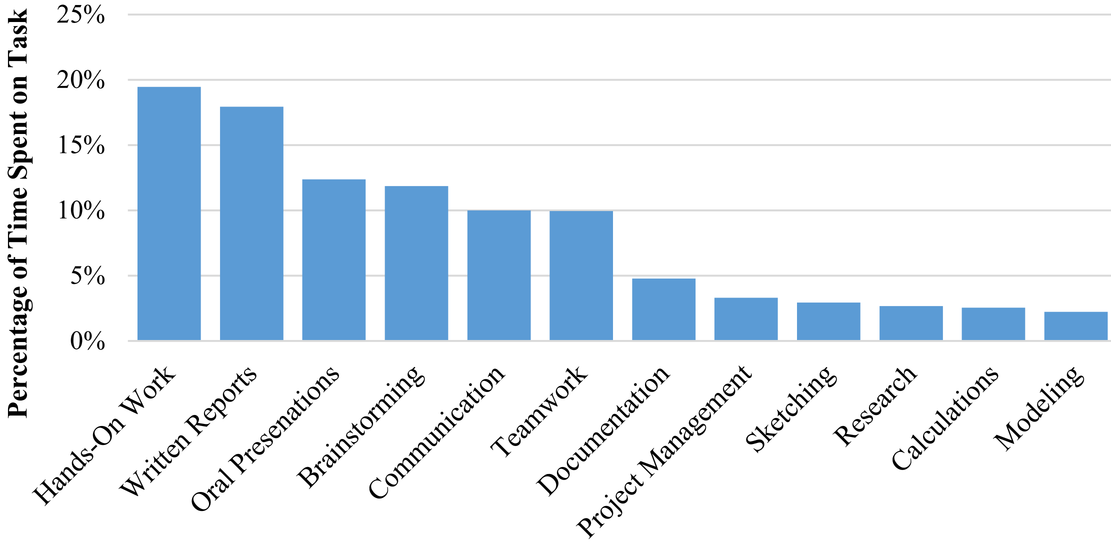

Figure 1. Proportion of time spent on different activity clusters.

Since we were studying project-based courses, it was expected that most students would spend a large portion of their time on Hands-On Work. The first-year design courses emphasize technical communication, and students reported spending approximately 40% of their time in this area (the proportion of time spent on Written Reports, Oral Presentations and Communication combined). This could either be because the technical communication workload is so high that students must devote a lot of time to it, or because students are writing and creating slides inefficiently, so it takes them more time to complete even simple technical communication tasks.

Pearson's correlation tests were conducted in determine if the proportion of time spent on different activity clusters correlated with changes in any engineering confidence or self-efficacy measures.

There were several correlations between time spent on tasks and changes in confidence measures (Table 2). It was found that Hands-On Work, Modeling, and Calculations positively correlated to changes in engineering confidence or self-efficacy measures.

Table 2. Significant correlations between time on task and changes in confidence and self-efficacy measures ($p<0.05$ by Pearson's correlation coefficient)

<table>
<tr><th colspan="2" rowspan="2">Measure Change</th><th colspan="2">Proportion of Time on Task</th></tr>
<tr><th>Positively Correlated</th><th>Negatively Correlated</th></tr>
<tr><td colspan="2">Commitment to Completing Degree</td><td>Hands-On Work</td><td>-</td></tr>
<tr><td colspan="2">Confidence in Completing Degree</td><td>Modeling</td><td>-</td></tr>
<tr><td rowspan="3">Academic Self-Confidence</td><td>Open-Ended Problem Solving</td><td>-</td><td>-</td></tr>
<tr><td>Math and Science</td><td>-</td><td>-</td></tr>
<tr><td>Professional and Interpersonal Skills</td><td>-</td><td>-</td></tr>
<tr><td rowspan="2">Self-Efficacy</td><td>Engineering</td><td>Calculations</td><td>-</td></tr>
<tr><td>Tinkering</td><td>Calculations</td><td>-</td></tr>
</table>

These findings correspond with past studies that have found that hands-on work is a key mastery experience for students.[22] It also appears that doing Calculations is an important mastery experience for first-year students, as spending more time on these math-heavy tasks correlates to an increase in both self-efficacy measures. This finding could align with other studies that have found that self-confidence in math and science skills are very important for first-year students to persist and succeed in engineering.[6,7]

It's worth noting that the positive effects on self-confidence and self-efficacy from Modeling and Calculations resulted from relatively small proportions of time spent on those activity clusters (2% and 3%, respectively). Instructors may want to consider that spending more time on these tasks could improve more aspects of students' engineering confidence or self-efficacy.

Does the goal orientation of the students affect the tasks that they choose to take on during their project?

Students may either have a performance goal orientation, in which they are focused on getting the best grade possible or completing the project quickly, or a mastery goal orientation, in which their main goal is to learn and develop skills.[16]

Students were asked in the semi-structured interviews how they chose to do particular project tasks to assess whether or not they had a performance or mastery learning goal orientation in the course. Zero students were perceived to have a mastery goal orientation, while many students described choosing tasks in a way that suggests that they have a performance goal orientation.

Almost every student, at some point in the interview, mentioned how limited their time was in the project and how that influenced the decisions their team made or the tasks that students took on:

> *I mean I wish I could have learned a little more CAD, obviously; but like obviously there's a lot of time constraints like a lot of other classes going on, so, and she knew how to do it, and obviously there was a lot of other work to do on the project as like a lot of the team wasn't. So I definitely—I was busy, but yeah, learning CAD would have been something I definitely wanted to try out.*

Many students mentioned that a team member took on a role due to previous experience, and that no one else knew how:

> *And then one person, there's like one is this CAD person. She did like the whole CAD model cause no one else knew how.*

In cases like these, student teams seem to have a performance goal orientation, because they are assigning tasks among the teammates based on what can be done in the shortest amount of time, as opposed to allowing students to gain new experiences. The students who don't already "know how" to do certain tasks may not have the opportunity to complete important mastery experiences and therefore not experience an increase in engineering confidence or self-efficacy. Instead, the students who already are confident in those skills will continue to be confident.

As instructors oversee first-year student projects, it is important to consider the goal orientation of the student teams. Projects are, of course, time-consuming, but students should not feel so time-starved that they do not feel comfortable or able to take on learning new tasks. It is also important to consider the goal orientation of the students or of teams as a whole. Students may feel pressured to divide tasks based on prior experience or confidence levels, thus forgoing the opportunity to learn new things and develop important skills.

Does the role that a student plays on their team affect which tasks they spend the most amount of time on over the course of the semester?

In the second semester of this study (Fall 2015), participants reported the roles they were playing on the project on each of the weekly logs. Figure 4 shows the number of times that role was selected by the students in their weekly logs over the duration of the project.

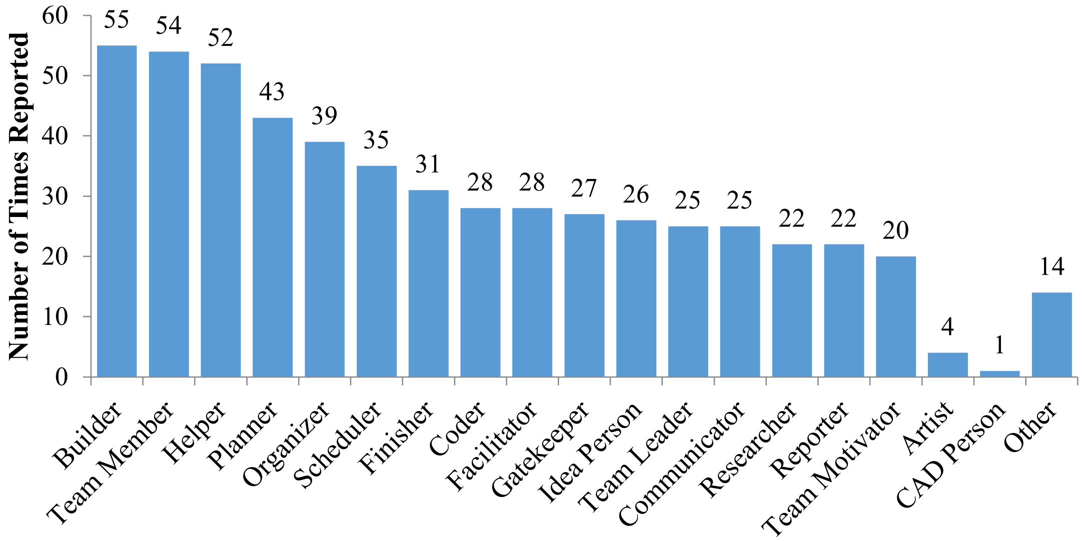

Figure 4. Number of times that students reported holding different roles.

The students rotated between four instructor-assigned roles: Facilitator, Gatekeeper, Reporter or Team Member. Besides the instructor-assigned roles, the top roles that were reported were Builder, Helper, Planner, Organizer, and Scheduler.

During the interviews at the end of the course, students were asked to list one to three roles that they took on in the project. The students were provided with a list of roles they could choose, but were also allowed to name different roles if they felt as though they played a role that was not listed. As the interviews were analyzed, a binary code was used to record whether or not the students had reported playing a certain role. If the students reported in the interview that they played a role, a 1 was recorded and if they did not report playing that role, a 0 was recorded. Also, the students were asked if they wished they had played different roles on their team. If the student wished they played a different role, a 1 was recorded, and if they reported being content with their roles, a 0 was recorded.

A Pearson's correlation test was then done to see if there were any correlations between the roles that students reported playing in the interviews, whether or not they wished to take on a different role, the time spent on various tasks, and their academic self-confidence and self-efficacy measures.

One interesting finding from this analysis is that there was a *negative correlation* between students identifying as being the leaders on their team and wishing that they played different roles over the course of the semesters.

Being the CAD person on the team was the only role that was correlated with a change in one of the measures from the pre- and post-project surveys: it correlated with an increase in the student's confidence in completing their degree.

There was also a negative correlation between students wishing that they had played a different role on their team and the change in their confidence in completing their degree. This shows that students who wished they had played different roles on their team than the ones that they played may feel less confident in completing an engineering degree. This is more evidence that students should be playing roles that allow them achieve their learning goals as it also increases their confidence about their ability to complete their degree.

Do male and female students complete different tasks in their teams?

Table 3 shows the roles that the interviewed student self-reported as having during the semester.

Table 3. Self-identified roles that students took on in teams.

Role	Male	Female
Idea Person	9.1%	0.0%
Helper	18.2%	0.0%
Leader	0.0%	9.1%
Finisher	9.1%	18.2%
Planner	9.1%	9.1%
Communicator	0.0%	18.2%
Builder	36.4%	18.2%
CAD Person	0.0%	18.2%
Servo	9.1%	0.0%

There is some evidence of gendered behavior. Thirty-six percent of men interviewed described themselves as taking on the role of Builders, while only 18% of women did. Eighteen percent of the women reported assuming the role of Communicator, while none of the men did.

However, there are also some findings that go against stereotypical gender roles: women were more likely than men to self-report as having taking on the role of Leader (9.2% compared to 0%) and CAD Person (18.2% compared to 0%). More men reported taking on a Helper role than women (18.2% compared to 0%). Thus, overall, there is no firm conclusion that first-year students are taking on gendered roles in teams.

However, if we consider the data beyond the first-year classes, gender may take more of a role in determining the students' project experiences. In the Spring 2015 study semester, sophomore and senior design classes were surveyed along with the first-year courses. T-tests were used to compare the data reported by male and female students in the pre- survey, post-survey and weekly logs. Table 4 present the significant ($P<0.05$) and not significant but borderline ($P<0.01$) differences between how men and women spent their time.

Table 4. Differences between men and women in the total time spent on activity clusters.

Course	P-Value	
	P < 0.05	***P < 0.1***
First-Year Course 1	-	-
First-Year Course 2	-	**Written Reports**
Sophomore ME Course	-	-
Senior ChE Course	**Communication**	**Calculations** *Hands-On Work* **Teamwork** *Written Reports*
Senior EECS Course	Only one woman participated so t-test could not be conducted for this course.	

Bold signifies women spending more time on this activity than men
Italics signifies men spending more time on this activity than women.

In one of the first-year classes, there were no significant differences between men and women. In the other first-year class, men spent more of their time on Written Reports than women. There were also no significant differences between men and women in the sophomore-level course. These findings were, overall, reassuring. However, in one of the senior-level courses, there were many significant differences between how men and women spent their time. Women spent more time on Communication, Calculations, Teamwork and Written Reports. Besides Calculations, activities were mainly communication-related activities, generally considered to be stereotypically "female" tasks.[18,23] Men spent more time on Hands-On Work, which is more often considered to be a "male" engineering task.

As there were few gender differences in the first- and second-year courses, but evidence of gendered behavior in the senior-level course, gendered roles may be developing over the course of the four years that engineering students spend at college. This is a potential area for future research.

Conclusions and Recommendations

In this study, we developed a better understanding of what students are choosing to do in project teams and which tasks correlate to increases in engineering confidence or self-efficacy. Students reported spending the most time on Hands-On Tasks and on technical communication (Oral Presentation, Written Reports, and Communication), with very little time spent on Modeling or Calculation. It can be seen that the tasks that students are spending the most time on may not be directly in line with the teaching goals for the course. Also, students may not be spending the most time on the tasks that benefit their engineering confidence or self-efficacy the most: only Hands-On Tasks, Modeling and Calculations positively correlated to changes in engineering confidence or self-efficacy, but students spent very little time on Modeling or Calculations. This means that instructors may need to consider the balance of tasks and also consider developing new aspects of their project that would give students the opportunity to spend more time on tasks that have been shown to lead to higher levels of confidence and self-efficacy. We also recommend that instructors spend more time asking students how they are spending their time in the project. Instructors should emphasize that all students must participate in various tasks and employ strategies to ensure that this is happening, such as assigning rotating roles, requiring students to complete time logs or reflections, or having check-ins with each team. Including participation as part of grading could encourage students to spend more time achieving their goals for the course.

After determining *what* students do in projects, we investigated *why* students choose to take on the tasks that they do. In this paper, we considered the students' goal orientation, the roles they played on the team, and gender.

Almost every student mentioned something in the interviews about not having enough time to complete the project (indicating a performance learning goal orientation) or students taking on roles that were already familiar to them. Many students reported that they wished they had more opportunities to play technical roles, and many of them reported that the students who played technical roles on the team already knew how to do these roles and that's why they were chosen to play them. There was also a significant negative correlation between students wishing that they took on a different role and a change in student's confidence in completing their engineering degree. These problems could be improved by having students rotate roles throughout the project so they take part in more activities that could improve their self-efficacy and academic self-confidence. Instructors could design individual tasks at the beginning of the course that would allow for all of the students to learn new skills. This way, even if the student did not play a certain role on their team, such as being the CAD person, they still would have developed this skill and may be more satisfied with their role knowing that they had still gained the same knowledge as the other students in the class. Asking students to identify goals for the project at the beginning of the semester could help the student decide what to spend more time on throughout the course and to ensure that they are developing the skills that they wish to develop.

When analyzing the different time spent on tasks between male and female students, there were some differences that aligned with stereotypical gender roles (men more often self-reported as a Builder, and women as a Communicator) and some that conflicted with stereotypical gender roles (women self-reported more often as a Leader and CAD Person while men more often self-reported as a Helper). However, there was little significant difference in how male and female students spent their time in projects; but, the gender gaps seem to become more substantial throughout the four years that students spend at the university as the senior-level chemical engineering course had many more difference between the amount of time men and women were spending on different tasks than the first and second year courses did as can be seen with the trends found in Table 4.

This study suggests several future research questions, including:

1. Would assigning students specific roles, based on individual learning goals, improve self-efficacy? Could teams consist of students with a variety of learning goals and be given tasks that were directly related to what they wanted to get out of the class?

2. Is there a way to make the project tasks more uniform in terms of workload and skill development for each student?
3. What traits, beyond the individuals that compose it, make a team more balanced than other teams? How much does team dynamic play into the confidence of a team or the confidence of each individual student on the team?

Answering these questions could help in designing projects where students are encouraged to take on roles that they might not feel confident about taking on. It could also help set up other interventions that encourage men and women to do similar types of tasks and could discourage gender divides in the roles men and women are playing from occurring.[17]

The mastery experiences that students complete in projects significantly affect their engineering confidence and self-efficacy. However, it is not enough to put thought into designing project statements and timelines and expecting student success. The results from this study show that it could be effective for instructors to make sure that work is divided evenly between students to ensure that they are all getting the same opportunities to participate in mastery experience throughout the year. We would recommend that instructors ask students to identify goals for the course at the beginning of the project and then periodically check in with them to make sure that they are working towards meeting the goals they identified at the beginning of the semester. This could lead to a larger amount of students experiencing positive changing in their academic self-confidence and self-efficacy.

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