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Abstract

Project-based learning can be beneficial for engineering students, giving students the opportunity to complete mastery experiences that improve their engineering self-efficacy or academic self-confidence. However, despite the many potential benefits of projects, there can be issues with project-based learning: students may take on different tasks than their teammates, thus developing different skills and having different mastery experiences; and projects may impact students' self-confidence or self-efficacy differently, and may depend on the students' gender or class standing. This paper presents the results of a mixed-methods cross-sectional study focused on project experiences of students in the first, second, and final year of an undergraduate engineering curriculum: specifically, on the tasks that students take on and their changes in engineering confidence and self-efficacy. It was found that students generally experienced an increase in engineering confidence or self-efficacy over the course of the project semester, regardless of gender or class standing. There were differences in confidence between men and women observed at the beginning of first-year courses, but not in later years in the curriculum. However, while there was little evidence of stereotypically gendered divisions of tasks (women spending more of their time on managerial or communication work, men spending more of their time on technical or hands-on tasks) in first-year and sophomore classes, this division was found in senior-year projects. Our work highlights that project-based learning is beneficial for students in terms of increasing their engineering confidence and self-efficacy, but this increase may not persist, as seniors (fourth-year students) did not have higher self-efficacy than first-year students.

Introduction

Project-based learning is a growing component of engineering curricula globally, giving students the opportunity to work in teams to apply and integrate prior knowledge to solve authentic problems (Mills & Treagust, 2003). For example, design projects in the final year of the curriculum ("capstone" projects) are an accreditation requirement in the United States (ABET, 2016), while first-year design courses ("cornerstone" projects) have become popular as a way to introduce students to engineering practice early in their program (Brannan & Wankat, 2005; Reid, Hertenstein, Fennell, Spingola, & Reeping, 2012). Project-based learning is primarily introduced as a way to provide students with authentic, valued skills for engineering practice, including collaboration, communication, and design. However, because students generally work closely with their peers in teams, project-based learning is much more socially situated than the more traditional approach to engineering education, which focuses on individual work and problems with closed solutions that are abstracted from their real-world context. A student's experience in a project-based course, particularly as it impacts individual development such as self-efficacy or identity, therefore results from the interaction of the design of the course with the learning and social environment of students. This study focuses on the interaction of project-based learning with (potentially gendered) task choice and the development of academic self-confidence and engineering self-efficacy in three different years of study within a specific institutional context; the larger goal is to illuminate these types of interactions more broadly, because they affect student experiences in important ways. Developing our understanding of how students approach project-based learning, and how the students' confidence or self-efficacy changes throughout this experience, will help us design learning experiences that make the most of the potential of this pedagogical approach in a wide range of cultural contexts. In particular, because self-confidence and self-efficacy are linked to persistence in the engineering degree and the profession, understanding how they are developed in project-based learning experiences will assist with both retention of engineers generally (thus helping to fill a global need for engineers) and well as addressing the specific needs of underrepresented groups.

In this work, we analyze the project experience for students by considering the tasks that students take on in project teams and the changes in their academic self-confidence and self-efficacy throughout the project course. We consider how this differs between male and female students and between students of different class level (meaning, the year of study; here, we consider three class levels: first year, sophomore and senior).

Mastery Experiences and the Development of Self-Efficacy in Project-Based Learning

Project-based learning has many potential benefits for students. Projects can improve students' conceptual understanding, problem-solving skills and understanding of how to approach professional practice (Mills & Treagust, 2003; Thomas, 2000), as students are required to apply their knowledge to an ill-structured, open-ended problem. Students have the opportunity to develop teamwork and communication skills, as they typically work in groups and share their work via oral presentations or written reports (Finelli, Bergom, & Mesa, 2010). Students who work on projects have been found to become more adaptable (Pavelich, Olds, & Miller, 1995) and have better attitudes toward the subject material (Thomas, 2000). First-year projects, in particular, can improve students' interest in and motivation to study engineering (Meadows, Fowler, & Hildinger, 2012; Mills & Treagust, 2003), thus increasing persistence and retention (Al-Holou et al., 1999; Anwar, Batzel, & Sell, 2004; Knight, Carlson, & Sullivan, 2007). Hands-on engineering projects carry specific benefits for students: "making" requires students to apply knowledge in a concrete way and thus can improve learning, and the existence of a physical product allows for students to better share and receive feedback on their design (Blumenfeld et al., 1991). Hands-on engineering project work has also been found to be linked to student understanding, adaptability, and design skills, and is considered to be one of the key mastery experiences for students (Miller, Bohmann, Helton, & Pereira, 2009). These types of mastery experiences, when students successfully complete the types of tasks that are part of professional practice, are a contributor to students' *engineering self-efficacy*, their belief in their ability to succeed at doing engineering work (Bandura, 1997). Mastery experiences have been found to be the most influential source of self-efficacy (Bandura, 1997; Zeldin & Pajares, 2000) and students rate them as the most impactful type of learning experience (Hutchison, Follman, Sumpter, & Bodner, 2006; Lent, Brown, Gover, & Nijjer, 1996). However, mastery experiences have been found to have more of an impact on the self-efficacy of men compared to women (Zeldin & Pajares, 2000), and they may have less impact than other contributors to self-efficacy for students who have little engineering experience, including first-year students (Hutchison-Green, Follman, & Bodner, 2008).

It is important that all students have a sufficiently high level of engineering self-efficacy as they continue in their academic career. Similarly, students need high academic self-confidence to succeed; in this work, academic self-confidence is considered to be a student's belief in their academic capabilities and likelihood to succeed, whereas self-efficacy refers to students' belief in their abilities to complete certain tasks. To begin with, students who enter engineering programs already typically have relatively high engineering self-efficacy, because they would not have chosen the field if they did not feel they could succeed (Bandura, 1997). Students who begin their studies with a lower level of academic self-confidence are less likely to persist (Besterfield-Sacre, Atman, & Shuman, 1997). Similarly, a student's engineering self-efficacy level can also impact the specific tasks that a student takes on: with high self-efficacy, they are likely to take on the specific tasks that they feel they can succeed at and persevere when they are challenging, regardless of their ability (Collins, 1984; Pajares, 1995), while students with low self-efficacy may avoid tasks because they are not confident that they will do well. Science, technical or engineering self-efficacy has been linked to persistence, interest, and performance (Chemers, Hu, & Garcia, 2001; Hackett, Betz, Casas, & Rocha-Singh, 1992; Ho & Raubenheimer, 2011; Hutchison et al., 2006; Lent, Brown, & Larkin, 1986; Lent, Larkin, & Brown, 1989; Multon, Brown, & Lent, 1991; Tsenn, McAdams, & Linsey, 2013). Self-efficacy and self-confidence therefore significantly influence how students proceed in their engineering studies and indeed, students who drop out of engineering programs have significantly lower academic self-confidence in math and science or in engineering than their peers who persist in the program (Besterfield-Sacre et al., 1997; Eris et al., 2010; Ohland, Sheppard, Lichtenstein, Eris, & Chachra, 2008).

Gender Differences in the Project-Based Learning Experience

Various studies have suggested that lack of academic self-confidence can play a role in students leaving the engineering major (Besterfield-Sacre et al., 1997; Eris et al., 2010; Ohland et al., 2008), particularly for women

(Seymour & Hewitt, 2000). Even students who left an engineering major in good academic standing have been found to have lower confidence in their engineering skills (Besterfield-Sacre et al., 1997). While some work has found that women and men have similar levels of engineering self-efficacy (Chachra & Kilgore, 2009; Hirshfield, Chachra, Finelli, & Goodman, 2015; Marra, Rodgers, Shen, & Bogue, 2009), particularly in later years in the program (Cabrera, Castaneda, Nora, & Hengstler, 1992; Concannon & Barrow, 2008; Huang & Brainard, 2008), a number of studies have demonstrated that women in STEM have lower academic self-confidence or engineering self-efficacy than their male peers despite similar or greater academic achievement or abilities (Adelman, 1998; Besterfield-Sacre et al., 1997; Besterfield-Sacre, Moreno, Shuman, & Atman, 2001; Brainard & Carlin, 1997; Brown & Latham, 2002; Chachra & Kilgore, 2009; Hackett, 1985; Ho & Raubenheimer, 2011; Huang & Brainard, 2008; Jones, Paretti, Hein, & Knott, 2009; Morozov, Kilgore, Yasuhara, & Atman, 2008; Pajares & Miller, 1994; Reisberg et al., 2010; Seymour & Hewitt, 2000; Strenta, Elliott, Adair, Matier, & Scott, 1994; Wilson, Bates, Scott, Painter, & Shaffer, 2015)(Jones et al., 2009)(Jones et al., 2009)(Jones et al., 2009)(Jones et al., 2009).

Over the course of their studies, women may not necessarily see gains in their academic self-confidence that are comparable to men. Women have been found to value group work more highly than male students because they believe they need aspects of it to succeed, such as assistance from other students (Felder, Felder, Mauney, Hamrin, & Dietz, 1995). However, women typically take a lesser role on project teams than men, and feel their contributions are undervalued (Felder et al., 1995; Seron, Silbey, Cech, & Rubineau, 2016), and thus may not be gaining knowledge, developing skills, or increasing their technical self-efficacy in concert with their male peers. For example, women take on less technical roles in their teams (secretary, writer, notetaker, etc.) and, during presentations, present non-technical content (like the introduction or conclusion) and answer fewer questions than male students (Meadows & Sekaquaptewa, 2013); their male peers are more likely to emerge as leaders and are perceived as more knowledgeable (Meadows & Sekaquaptewa, 2011). This may mean that women are feeling more confident in non-technical roles, but by not gaining self-efficacy related to specific technical engineering work, women may be less likely to persist. Even with a learning intervention in place to draw attention to stereotypically gendered task allocation, it was found that women continue to take on more of a writing role than their male peers (Stein, Aragon, Moreno, & Goodman, 2014). Unsurprisingly, therefore, it has been observed that female students show less of an increase in engineering self-efficacy than their male counterparts as a result of team-based, hands-on engineering projects (Masi, 2009). Thus, one focus of this work is to compare the mastery experiences (tasks) that male and female students take on in project teams, and compare the changes in engineering confidence and self-efficacy for each group.

Class Level Differences in the Project-Based Learning Experience

We also focus on how the project experiences compare across the curriculum, using data from first-year, sophomore (second year) and senior (final year) students engaged in hands-on engineering team projects. Ideally, project experiences throughout the curriculum will consistently provide mastery experiences for students, thus increasing students' confidence and self-efficacy, so that students are not just fully prepared but also feel capable to succeed at their professional work upon graduation. However, results from studies comparing the confidence of students in different class levels of the curriculum have varied. It has been found that first-year students' self-efficacy increases while partaking in project-based learning (Masi, 2009; McKenna & Hirsch, 2005), while sophomore students' self-efficacy *decreases* (Masi, 2009); this suggests that projects can impact students of different class levels differently.

Studies have shown that there was no difference in confidence or self-efficacy between students in different class levels (Trivett, Kotys-Schwartz, & Cyrus, 2011; Tsenn et al., 2013); that is, despite generally knowing *less* about engineering principles, first-year students have the same or higher engineering confidence or self-efficacy as upper-year students. For female students, specifically, it has been found that confidence is never as high as it is when students begin the undergraduate curriculum (Brainard & Carlin, 1997). Similarly, male and female students have similar levels of confidence in their math and science ability in elementary school, but by high school, men report higher confidence (Dossey, 1988; Eccles, 1994; Linn & Hyde, 1989). Together, these findings imply that: first, students may not experience a monotonic increase in self-confidence or self-efficacy throughout the curriculum or throughout a project experience. Second, project-based learning may impact students differently in terms of affecting their self-confidence or self-efficacy. Thus, the second focus of this work was to consider how projects impact students differently in each year of study, and how their confidence and self-efficacy may change over the project course.

Research Questions

In this work, we considered students engaged in various project experiences across the curriculum to investigate how projects impact the development of engineering confidence and self-efficacy for male and female students in their first year, sophomore year, or senior year of the undergraduate curriculum. Specifically, we analyzed the mastery experiences (tasks) that students take on in project teams and the changes in engineering confidence and self-efficacy over the project course in each class level. We compare and contrast the datasets in two different ways. One, we compared the experience between male and female students within each class level. Also, we compared the experiences of students in each class level (the first year, sophomore or second year, and senior year). This analysis allowed us to address the following research questions:

1. How does the academic self-confidence and self-efficacy change throughout the project experience for students of each class standing?
2. What differences exist in academic self-confidence and self-efficacy measures between male and female students?
3. What differences exist between male and female students in proportion of time devoted to different types of task?

Method

Data Collection

This study is a cross-sectional mixed-methods study, in which we collected data on the experiences of students throughout their engineering degree program over the course of a single semester, including first-year students, sophomores (second-year students) and seniors (students in their fourth and final year of the degree program). This study used a mixed-methods concurrent nested approach to data collection and analysis; both quantitative and qualitative data were collected and then integrated upon analysis (Creswell, Plano Clark, Gutmann, & Hanson, 2003). Quantitative data included pre- and post-course surveys and weekly activity logs, while qualitative data included semi-structured interviews conducted after the project course concluded. The timeline of data collection is represented in Figure 1.

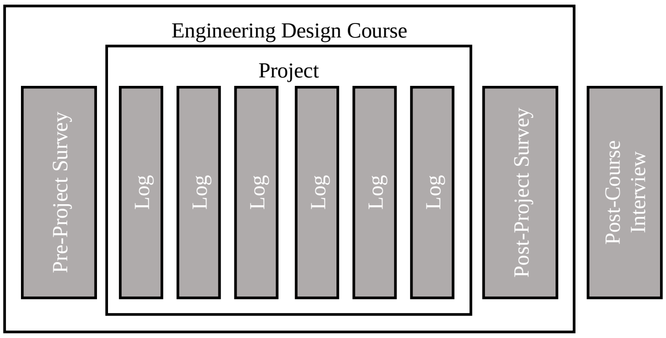

Figure 1. Data collection timeline

Pre- and Post-Project Surveys

In the pre-course survey, students reported their prior experience in engineering and their demographic background, completed questions from a simplified measure of the Big 5 personality traits (Gosling, Rentfrow, & Swann, 2003), and responded to items from seven different constructs which gauged their engineering confidence and self-efficacy (Appendix A), drawn from previously published studies. These instruments allowed us to consider the influence of demographics and personality type on teaming behavior.

Five of these measures or constructs were subsets of the Persistence in Engineering survey (Eris et al., 2005): (1) Confidence in Completing an Engineering Degree; (2) Commitment to Completing an Engineering Degree; Academic Self-Confidence in (3) Open-Ended Problem-Solving, (4) Math and Science Skills, and (5) Professional and Interpersonal Skills. Two instruments (Baker, Krause, & Purzer, 2008) assessed (6) Technical Self-Efficacy and (7) Tinkering (‘hands-on’) Self-Efficacy. The Persistence in Engineering survey instruments were used to assess general academic self-confidence in the areas relevant to engineering students; the two self-efficacy instruments specifically targeted engineering skills or hands-on project work. The Persistence in Engineering survey was previously validated by the survey developers (Eris et al., 2005), while the Technical and Tinkering Self-Efficacy instruments were validated in a prior iteration of this study presented here (Hirshfield et al., 2015). Each measure involved students rating their confidence in completing relevant tasks on the Likert scale (from 1-7 for the Academic Self-Confidence measures, and from 1-5 for all other measures). The post-course survey utilized the same questions related to the seven measures, in order to determine how engineering confidence or self-efficacy changed over the course of the project.

Weekly Activity Logs

In the weekly activity logs (Appendix B), students reported the number of minutes they devoted to different engineering-related project tasks in that week. Students were provided with a list of 40 tasks that they could report spending time on. This list of 40 tasks was derived empirically from activities undertaken in a first-year hands-on project course, as part of the preliminary work for this research project (Chachra & Kilgore, 2009). Students were also able to write in tasks that were not captured by the list, although as no students did so, the list of 40 tasks was presumed to be comprehensive. The tasks were grouped together into two kinds of clusters for analysis:

- *Mastery Clusters* are groups of tasks that map directly to items from the instruments used to measure Academic Self-Confidence and Self-Efficacy. The Academic Self-Confidence mastery clusters are Problem-Solving, Math & Science, and Professional & Interpersonal Skills. The Self-Efficacy mastery clusters are Engineering and Tinkering. Tasks could belong to more than one cluster. For example, the task “preparing written materials” is included in both the Academic Self-Confidence: Professional & Interpersonal Skills cluster (because students self-rated their confidence in “communication skills” in this instrument) and in the Technical Self-Efficacy cluster (because students rated their confidence in “written and oral communication skills” in this instrument).
- *Activity Clusters* categorized the 40 tasks within twelve over-arching types of tasks found in design or project work (Crismond & Adams, 2012). The activity clusters were Brainstorming, Calculations, Communication, Documentation, Hands-On Work, Modeling, Oral Presentation, Project Management, Research, Sketching, Teamwork and Written Report. Each task was part of only one Activity Cluster.

Semi-Structured Interviews

A subset of students participated in semi-structured interviews conducted at the conclusion of the course. All students were invited to participate in interviews, and all students who agreed to participate were subsequently interviewed. Interviews were conducted by a researcher who had no academic connection to the course in which students were enrolled. The one-on-one interviews generally lasted 30-45 minutes and were audio-recorded; the recordings were then transcribed for analysis.

Students were asked about their project and team experience, including how their team made decisions and the tasks that they and their teammates completed for the projects. For this paper, we focus on one portion of the interview, in which students were asked to describe the tasks that each member of their team completed, to assign roles to each team member, and describe which roles and tasks they took on individually. During the interview, this discussion was facilitated by providing the interviewee with a set of ‘role cards’ that identified approximately fifteen possible roles commonly taken on in teams, derived from preliminary interviews (for example, “leader,” “builder,” “finisher,” “idea person,” “cheerleader”) could be used to associate a set of roles with each team member. Students were also provided with blank cards to provide their own role names for team members.

Data Analysis

To address RQ1, pre- and post-project survey data was analyzed in SigmaPlot. Survey participants’ data were analyzed using paired t-tests, to determine if there was a statistically significant change in any of the seven confidence and self-efficacy measures from the pre-project survey to the post-project survey. Analysis of variance (ANOVA) was used to compare the data between each of the three class standings. To address RQ2, t-tests were used to compare the pre- and post-project survey data for male and female students within each class standing, to determine if there was a statistically significant difference between male and female students in any of the seven confidence or self-efficacy measures. ANOVA was used to compare the data for male students between each class standing and for female students between each class standing.

Students reported the number of minutes devoted to different project tasks on the weekly logs. The number of minutes devoted to each project task were converted into proportion of time devoted to each task, which accounted for missing logs by normalizing the student responses to the number of weekly activity logs each completed. To address RQ3, t-tests were used to compare the proportion of time male and female students within each class standing spent on individual tasks and task clusters; again, ANOVA was used to compare the data for male students between each class standing and for female students between each class standing. Semi-structured interview transcripts were analyzed using the NVivo qualitative analysis software tool. Fully coded findings are not presented here; quotes from interview transcripts are primarily included for illustrative purposes, providing context and nuance around the quantitative findings.

Participants and Settings

This paper presents data collected from 111 students in the college of engineering at a large public university in the Midwestern United States. Students were enrolled in one of five different project-based design courses during the second semester of the 2015 academic year. Descriptions of the courses can be found in Table 1, and the description of the student participants is in Table 2.

Table 1. Descriptions of the class settings studied in this paper

Class Standing	Course Descriptor	Course Description
First-Year	**FY-A**	A first-year course where teams design, build, and test a human-powered generator. Students apply principles of force, power transmission, electrical and magnetic circuits and electrical energy generation. This course also has an emphasis on technical communication.
	FY-B	A first-year course where teams of students design, build, and test an underwater Remotely Operated Vehicle. Topics include 3D modeling, system design, technical documentation, and team communication. This course also has an emphasis on technical communication.
Sophomore	**SO**	A sophomore level course where students are introduced to basic mechanical design and manufacturing. Students work in teams and are exposed to CAD systems and machine shop technique.
Senior	**SR-A**	A senior level class where teams produce a consumer-ready prototype of a chemical product. Students prepare oral, written, and economic reports about the product that their team developed.
	SR-B	A senior level class designed to give students a hands-on introduction to robotics from a computer science perspective, with an emphasis on laboratory design and programming of a robotic system.

All students listed in the table participated in the pre-course survey, weekly activity logs and/or the post-course survey. Thirty-one of those students (15 men and 16 women) also participated in a post-course interview. Of the interviewed students, 11 were first-years (4 in FY-A, 7 in FY-B), 12 were sophomores, and 8 were seniors (6 in SR-A and 2 in SR-B). Note that in this paper, we utilize binary gender designations (male/female); students were given the opportunity to self-identify as a non-binary gender, but no students self-identified as such.

Table 2. Student participants

		Number of Students			
Class Standing	**Course Label**	***Male Students***	***Female Students***	***Did Not Disclose Gender***	***Total***
First-Year	FY-A	11	7	0	18
	FY-B	15	9	1	25
Sophomore	SO	28	16	1	45
Senior	SR-A	7	11	0	18
	SR-B	5	1	0	6
	TOTAL	66	44	2	112

Results

RQ1: How does the academic self-confidence and self-efficacy change throughout the project experience for students of each class standing?

Students in each class standing generally showed an increase in engineering confidence and self-efficacy over the duration of the study (Table 3).

Table 3. Average engineering confidence and self-efficacy measures

		First Years		**Sophomores**		**Seniors**	
		Incoming	***Outgoing***	***Incoming***	***Outgoing***	***Incoming***	***Outgoing***
Commitment to Completing Degree		0.92	0.91	0.93	0.93	0.98	0.99
Confidence in Completing Degree		0.92	0.93	0.92	0.95	0.98	0.99
Academic Self-Confidence	***Open-Ended Problem-Solving***	0.84	0.87	0.82*	0.88*	0.82*	0.87*
	Math and Science	0.88	0.88	0.85	0.87	0.88	0.89
	Professional and Interpersonal	0.76*	0.83*	0.77*	0.81*	0.76*	0.84*
Self-Efficacy	***Technical Self-Efficacy***	0.75*	0.82*	0.78*	0.83*	0.823*	0.819*
	Tinkering Self-Efficacy	0.73*	0.77*	0.78	0.81	0.79*	0.81*

* denotes a significant change from incoming to outgoing at $p<0.05$.

For each class, students began and ended the project with the same high Confidence in and Commitment to Completing their Degree, suggesting that engineering students in this study were devoted to pursuing their engineering degree regardless of academic self-confidence or self-efficacy in specific areas. Another measure that did not have any significant changes over the semester of the project course was Academic Self-Confidence in Math and Science. This could be because students rated this measure as the highest of all academic self-confidence and self-efficacy measures; because their confidence was already so high, there was little room for increase. However, the lack of increase could also be because students were not evaluated in the project specifically on their math and science capabilities (although each project did incorporate some calculations or scientific principles) and students' self-perceptions of engineering confidence or self-efficacy are highly context-dependent (Hutchison-Green et al., 2008). Students may also have been impacted by the other courses they were enrolled in that semester. First- and sophomore students were concurrently enrolled in large, high-level calculus courses, and their experiences in these courses were likely to be contributors to Academic Self-Confidence in Math and Science. This is illustrated by the experience of one female sophomore, who said: "I kind of suffered through math but it got to the point where I just didn't really know how to study and I ended up sitting down for like eight hours a day."

In contrast to their Academic Self-Confidence in Math and Science, first-year, sophomore, and senior students all experienced a significant increase in their reported Academic Self-Confidence in Professional and Interpersonal Skills. Sophomores and seniors also experienced a significant increase in Academic Self-Confidence in Open-Ended Problem-Solving. Because each of the projects were designed with these specific types of tasks in mind, this finding is encouraging and suggests that students are engaging in the intended mastery experiences. In this case, it seems that by working in teams and on communication tasks, students became more confident in Professional and Interpersonal Skills; and by working on a project with less constraints and information than a typical homework problem, students developed increased self-confidence in their Open-Ended Problem-Solving abilities.

Students of each class standing also experienced a significant change in Technical Self-Efficacy; while for first-year and sophomore students that change was positive, senior students experienced a *decrease* over the course of the semester. This suggests that students earlier in their program of study may benefit more from projects than seniors, in terms of feeling more capable in technical engineering tasks. Given that the seniors are just about to graduate and apply their engineering skills in practice, it might be surprising that Technical Self-Efficacy falls in the semester prior to graduation. However, this fall in self-efficacy may reflect the authentic nature of the senior project. These students were participating in a rigorous senior design class that required students to apply knowledge from the entire engineering curriculum, whereas the first-year and sophomore courses were far more narrowly focused, reflecting the limited engineering experience that students early in their academic year have to draw on. When senior students are asked to call upon and integrate material that was learned in earlier classes, they may be realizing how much they do not remember. The senior design projects were also more authentically contextualized than the other projects. Seniors designed and fabricated products that had to fulfill a real human need, and they demonstrated those solutions at an event open to the public. In contrast, first-year and sophomore students were given a specific project brief and their final prototype was only seen by their classmates and instructor. This authentic contextualization of upper-year projects meant that students who excelled at doing calculations or memorizing equations may still have felt ill-equipped when faced with “real world” concepts. As a male student from SR-A noted:

> *If I get a reactor in the real world I would have no idea how to run a reactor, and I guess I could run equations and figure out how to run it, but I wouldn't be confident to run it by myself. I would need a mentor for a while, and then I would probably be confident of being able to do decisions.*

Similarly, a male student in SR-B said that the project made him realize how difficult it was to make something work in practice:

> *We had this little minibot that can drive around and pretty much you tell it to go straight and it won't go straight. And so that's like the biggest thing I learned, you need a ton of just like things to factor in like, oh, the ground may not be straight or there's dirt on the ground or something. And there's just all these tiny little factors that I never thought about.*

The increased complexity of an authentic project experience, coupled with the fact that students were about to leave the confined academic environment and begin their careers as engineers, may have led the seniors to reflect on how much they do *not* know, and thus to feel less capable (Kruger & Dunning, 1999).

First-year and senior students experienced a significant increase in Tinkering Self-Efficacy, which is especially notable because the sophomore class (a mechanical engineering design and manufacturing class) was designed to focus specifically on “tinkering” skills, including hands-on work, fabrication, machining parts and assembling a robot. This suggests that students may not experience an increase in Tinkering Self-Efficacy even when they are expected to do significant work in that space. Students may have also felt overwhelmed working on an open-ended project with relatively little structure, which is different from both their more traditional engineering classes and from the more structured first-year projects. As one sophomore student noted:

> *I didn’t think that we’d have as much freedom as we had in terms of basically doing everything starting from the ground up and actually building a robot and designing it in CAD and being—or having to machine within tolerances and all of that kind of stuff and be graded on that.*

RQ2: What differences exist in academic self-confidence and self-efficacy measures between male and female students?

There were very few differences between male and female students in terms of academic self-confidence and self-efficacy measures, both at the beginning of the project course and afterwards (Tables 4a and 4b).

Table 4a. Average engineering confidence and self-efficacy measures for female students

		First Year Women		**Sophomore Women**		**Senior Women**	
		Incoming	***Outgoing***	***Incoming***	***Outgoing***	***Incoming***	***Outgoing***
Commitment to Completing Degree		1.00	1.00	1.00	1.00	1.00	1.00
Confidence in Completing Degree		0.80*	0.80*	1.00	1.00	1.00	1.00
Academic Self-Confidence	***Open-Ended Problem-Solving***	0.81	0.86	0.86	0.88	0.79	0.86
	Math and Science	0.84	0.85	0.86	0.83	0.90	0.88
	Professional and Interpersonal	0.75	0.86	0.76	0.81	0.73	0.83
Self-Efficacy	***Technical Self-Efficacy***	0.71	0.80	0.77	0.80	0.79	0.79
	Tinkering Self-Efficacy	0.68*	0.75	0.82	0.79	0.77	0.79

* denotes a significant difference between male and female students at $p<0.05$.

Table 4b. Average engineering confidence and self-efficacy measures for male students

		First Year Men		**Sophomore Men**		**Senior Men**	
		Incoming	***Outgoing***	***Incoming***	***Outgoing***	***Incoming***	***Outgoing***
Commitment to Completing Degree		1.00	1.00	1.00	1.00	1.00	1.00
Confidence in Completing Degree		1.00‡	1.00‡	1.00	1.00	1.00	1.00
Academic Self-Confidence	***Open-Ended Problem-Solving***	0.87	0.88	0.84	0.89	0.86	0.89
	Math and Science	0.91	0.89	0.86	0.90	0.86	0.90
	Professional and Interpersonal	0.76	0.86	0.79	0.82	0.81	0.86
Self-Efficacy	***Technical Self-Efficacy***	0.77	0.83	0.79	0.83	0.86	0.80
	Tinkering Self-Efficacy	0.76*	0.79	0.79	0.82	0.81	0.79

* denotes a significant difference between male and female students at $p<0.05$.

The only significant differences in confidence or self-efficacy between male and female students were observed for the first-year courses. Female students began the semester with lower Tinkering Self-Efficacy than their male peers, but this gap closed over the course of the project. This is consistent with other work that suggests that women benefit more than men from project work (Terenzini, Cabrera, Colbeck, Parente, & Bjorklund, 2001); in this case, they benefitted in terms of feeling more capable in their hands-on design work. However, female first-year students entered *and* exited the project course with significantly lower Confidence in Completing their Degree, compared to their male counterparts. This suggests that although female students benefited from the project in terms of Tinkering Self-Efficacy, it did not translate directly into feeling more capable about completing their engineering degree.

However, after the first year, there were no significant differences in academic self-confidence or self-efficacy between male and female students. Students of both genders were similarly confident entering their sophomore and senior courses, and their confidence benefited similarly from the project, as evidenced by the lack of a difference in these metrics at the conclusion of the semester. While this may be reflected in their increased Confidence in Completing their Degree, given the relationship between Confidence in Completing their Degree and persistence (Eris et al., 2010), this may reflect that those less confident students may have left the program.

RQ3: What differences exist between male and female students in proportion of time devoted to different types of task in each class level?

Although there were no gender differences in engineering confidence or self-efficacy after the first-year, there were observed gender differences in the proportion of time devoted to different tasks later on in the curriculum (Table 5). Note that SR-B is not present in this section because there was only one female study participant and thus statistical comparisons between male and female students could not be made.

There was one significant difference in one first-year class (FY-B) in the proportion of time that students devoted to tasks: women spent a *smaller* proportion of their time on the Written Report than men (10.5% of their time as opposed to 17.7%). This finding is encouraging in that writing is a more stereotypically “female” task and other studies have reported that male first-year engineering students do less of this type of work in project teams (Crismond & Adams, 2012; Meadows & Sekaquaptewa, 2011, 2013). This finding suggests that there could be elements of the first-year course structure that support a more equitable distribution of tasks, or that students entered the curriculum with lower gender bias.

While there were no significant differences within the sophomore level class, results from SR-A (one of the senior courses) suggest that gendered task allocation remains an issue. In SR-A, women spent significantly more of their time on two types of tasks: women reported spending 10.4% of their course time on Communication, as compared with men spending 4.3%, and they spent 65.2% of their time on Professional and Interpersonal tasks, while men spent 38%. Although these were the only *significant* differences, note that there is stereotypically gendered division of many other task clusters (where $0.05 < p < 0.1$): men spent almost double the proportion of time on Hands-On Work, Research, Open-Ended Problem-Solving and Tinkering Tasks, while women spent far more of their time than men on the Oral Presentations and the Written Report. One female student in SR-A described how she did spend more time on technical tasks as the semester went on, but that her main role was to work on the team presentations:

> *I've worked with CAD, but I want to be the type of person that's hands-on and can do stuff like that, but still kind of like not my strongest point. I'm more like I'm very good at planning or hypothesizing maybe what's going to occur, but when it's actually in the process of building things and doing things it's not my best. So, at the beginning I probably did more of PowerPoint stuff. And I did not as much research then. I was still a little unsure about our product and our project. But then moving forward I was able to become more confident and I started doing more hands-on things. I researched more. I was more willing to discuss while we were together about our project and what we thought. And I helped a lot with the prototyping, like running tests. And obviously I've worked a lot with, like, me and [my teammate] made the poster. Normally I'd revise PowerPoints, if we have a PowerPoint.*

Table 5. Proportion of time spent in each task cluster, for male and female students.

		FY-A		**FY-B**		**SO**		**SR-A**	
		Female Students	Male Students	Female Students	Male Students	Female Students	Male Students	Female Students	Male Students
Activity Clusters	Brainstorming	9.4%	15.6%	8.4%	11.4%	13.4%	18.4%	14.6%	17.7%
	Calculations	3.2%	2.7%	2.6%	2.7%	2.3%	2.3%	1.8%	1.0%
	Communication	8.3%	5.3%	5.1%	4.9%	4.8%	7.2%	10.4%*	4.3%*
	Documentation	4.7%	2.0%	1.8%	2.7%	2.1%	1.2%	3.6%	4.1%
	Hands-On Work	10.8%	15.6%	31.9%	23.9%	32.6%	28.5%	10.7%	21.9%
	Modeling	0.7%	1.5%	5.4%	3.5%	12.8%	10.6%	0.4%	0.1%
	Oral Presentation	19.4%	14.5%	24.2%	17.8%	14.3%	10.6%	16.6%	10.3%
	Project Management	5.5%	8.9%	2.8%	2.2%	3.0%	3.4%	10.3%	7.3%
	Research	2.3%	2.4%	2.5%	3.4%	1.7%	3.2%	8.6%	21.5%
	Sketching	3.3%	2.6%	2.9%	6.0%	2.9%	4.9%	0.5%	0.5%
	Teamwork	5.2%	7.0%	1.9%	3.9%	2.8%	3.6%	6.0%	4.4%
	Written Report	27.2%	21.9%	10.5%*	17.7%*	7.3%	6.0%	16.7%	7.0%
Mastery Clusters	Open-Ended Problem-Solving	18.8%	26.9%	32.3%	32.4%	35.2%	40.8%	31.8%	50.8%
	Math and Science	7.2%	9.1%	4.6%	6.6%	8.6%	7.6%	2.4%	8.1%
	Professional and Interpersonal	70.7%	59.7%	47.0%	50.6%	34.8%	32.2%	64.2%*	38.0%*
	Technical	77.2%	73.7%	64.3%	68.4%	79.4%	80.5%	67.0%	68.2%
	Tinkering	14.8%	19.7%	40.3%	33.3%	48.3%	44.0%	13.8%	22.4%

* denotes significant difference between male and female students at $p<0.05$.

In fact, many female students across all class levels described being "split" between technical and non-technical work. Another female SR-A student reported that she took on presentation work because "we need to divide up the work somehow; I'm going to work on the poster, let's figure out who can do what." Other female students in SR-A reported feeling that they were "nagging" their other teammates, "constantly emailing or texting or bugging the group" which made them feel "pushy." A sophomore student noted "I feel like I made a lot of sacrifices...I did a little bit of everything." Many first-year female students discussed being the one to make the final touches on their reports, even staying up late to do so because another student did not complete their part properly. One student described herself as taking on the role of "finisher:"

> *I did a lot of the planning for when we were going to meet together, planning and communicate I'd say. I would always be the one to print it off and turn it in, edit. like. the reports, and so in that sense kind of a finisher. I felt like I didn't really choose to be, like, the finisher, but everyone would always end up saying, "Okay, can you print this out? Can you make sure that it gets submitted online?" I'd be like, okay, yes, and then that kind of just stuck with me and I would always be the last one to look over everything and turn it in. So that was kind of stressful because it had to be like at night sometimes and get late when everyone else would have left… I think because they knew that I was responsible and that I wouldn't just let it—I wouldn't turn it in unless it was good enough. So I think they could trust me with that, and I would always probably be the last person at the meetings.*

Taking on this role in a team could be detrimental to female students' project experience in many ways: they have to undertake the emotional labor of managing their team (and may feeling uncomfortable doing so), they cannot necessarily focus on one single task and instead are split between many, and they may take on roles they do not want to because they want to make sure that all of the work gets done. For example, one male student in SR-A noted how the female students on his team would "just say yes," and that he enjoyed group work because he did not have to do the tasks that he did not like:

> *[She] was very pacifist. She would normally just say yes…what I liked most about working in a team is that I don't have to do the stuff that I really hate. [laughs] So there's things I do not enjoy. A lot of the writing, a lot of the revising and things that don't really add value I do not enjoy… So I think that's what I like about teams, that there's people that do like that, so you can kind of split up, and people can do what they're good at, and I think that's what I like the most.*

It could have been that the female student that he described took on more of the writing because she enjoyed it, as he hypothesized. Or, it could have been because, as a "pacifist," the female teammate would take it on since *someone* in the team had to do it, and female students may more often take on leftover roles rather than assert themselves on their teams (Meadows & Sekaquaptewa, 2011) in order to take on the roles that they would prefer.

Discussion

Over the course of four years, the self-confidence and self-efficacy of male students was not observed to increase at *all:* there were no statistical differences in any measure from the first-year students through the senior students (Table 4b). Although this is a cross-sectional study comparing different students, these findings suggest that male students may not have higher confidence in later years of the curriculum. This aligns with prior research finding that confidence may not increase monotonically (Brainard & Carlin, 1997; Chachra & Kilgore, 2009; Tsenn et al., 2013). However, in considering the female students in this study, a number of measures of academic self-confidence and self-efficacy *are* higher course of the curriculum (Table 4a), with significant increases occurring in the first year. This could suggest that women's confidence is more sensitive to changes in the specific academic context, such as the project environment, or other contexts, such as their experiences in the dorms or in campus life. However, there was only one significant difference found when comparing female students' measures of each class standing: female sophomore students had a higher Tinkering Self-Efficacy than female first-year students (p=0.03). This suggests that female students may feel more comfortable with hands-on work later in the curriculum, although that increased self-efficacy may not persist (as seniors did not have a higher Tinkering Self-Efficacy than sophomores or first-years).

On the face of it, the lack of significant differences in engineering confidence or self-efficacy between the students of each class level suggest that project courses (and more broadly, the engineering curriculum in its entirety) may not significantly impact students' confidence in a lasting way: students are not becoming more confident as a result of learning more. This may be because, as students persist in the curriculum and develop their knowledge and skills, they have a better understanding of what they have yet to learn, and their self-rated self-confidence and self-efficacy reflects this (Kruger & Dunning, 1999).

Students also may be benchmarking themselves to their peers, as opposed to comparing themselves to their own confidence and ability level at a prior point in the curriculum; in other words, they see themselves at the same ability level each year relative to their peers, but are not considering how much more capable they are than the year prior. As one sophomore student noted, “in my other classes I do well but it feels like ‘oh, these kids are so smart, I’m not that smart.’” On the contrary, one senior-level female student noted in her interview that she was more confident as a senior, compared to when she was a first-year:

> *My role [on the project team] was very different now compared to when it was when I was a freshman. Felt like I was much more likely to, like, take control or tell people, “Okay. We have to get this done." In [the first-year class], I was very timid….in [this course], was my first push to becoming more confident and gaining leadership skills and everything and then this course kind of I think drove me even more so.*

Regardless, although students may not be gaining confidence over the course of the curriculum, that does not mean that the project experience is insignificant, as they are certainly applying knowledge and developing important skills, as one sophomore student noted:

> *I really love that we have a design class every year. I think that’s absolutely the best thing you can do for engineers. I’m on a design team so I get that experience anyways but my classmates don’t. And I really enjoy those classes. I put most of my effort into those classes because I know that’s what you get the most out of is the design class because you get to apply what you’ve learned in your other classes.*

The findings that there was no stereotypically gendered division of tasks in the first year and sophomore, but there was in the senior year (Table 5) suggest that over the course of the undergraduate curriculum, students feel *more* inclined to gendered behavior. Although students may have preconceptions about gender dynamics in engineering before they begin college, those biases did not manifest in the first-year or sophomore courses in terms of task allocation; this could be due to teaming experiences that are carefully scaffolded in the early years to ensure that all students participate. Or, this increasingly gendered task division in senior year may be due to the accumulated effect of women feeling that they “splitting” their time between technical and non-technical tasks more than their male peers, and thus feeling less qualified to take on the more technical work in subsequent courses.

The gender differences may also result from social factors in the learning environment: women may be more affected by stereotype threat, whether that is because of the continual male majority in both their classes and the faculty; the male-coded climate of engineering (Tonso, 1996); or some other type of discouragement to persist in the major, such as sexist behavior or microaggressions. For example, one female sophomore student noted always having to “prove herself” as a female engineer, particularly with hands-on tasks:

> *You feel like you have to prove yourself every time. It's just kind of assumed that 'cause you're female you're incompetent. It's just kind of an assumption. Not necessarily incompetent with the math and science, but you assume that females don't have any hands-on experience, just 'cause it's always the boys that are taking apart their car and fixing it. And I have less experience taking apart cars and fixing it. In the [student design center], everyone knows me, and I'm perfectly well accepted as just as equal as a guy. And I think that's fair, and I have proved myself there. But you go to the mechanical engineering shop, and I think the first day I was using a lathe there, because I'm a lathe trainer at the [student design center]. I know how to use a lathe. I asked some question, 'cause their collet system was weird. And then after that, like every five minutes, the guy would come by and be like, "Do you need any help?" And I was like, "Actually, I got it. I'm good." And like I told him the first time, "I know how to use the lathe. I just wasn't sure how the collet worked." And then he'd come back, "How are you doing? Do you need any help?" And I'm like, "Actually, I don't. I'm actually good." And one of the guys that works there realized, like, "Yeah, she knows what she's doing. She's fine." And so you kind of have to—once you prove yourself, you're good. But if I was a guy and I'd asked a question about the collet system, I don't think I would have gotten help every five minutes and checking in to see how you were doing. But I think once you prove yourself, it's fine. It's just kind of you have to take that extra step to show that you do know what you're doing.*

Limitations

This study is a cross-sectional snapshot of a set of project courses over the course of a four-year engineering program at a large public university in the Midwestern United States. While these courses are likely to be representative of many similar schools, they are also individual courses, with the specificity that implies and reflecting the experiences of a relatively small number of students. While the overall patterns we observed are consistent with findings on academic self-confidence and on gendered behavior from other studies, we also note that this specificity matters: that the data presented here (together with earlier studies) suggests that the development of academic self-confidence and engineering self-efficacy, as well as task division on teams, are sensitively dependent on the details of student academic experience. This, in turn, suggests that the thoughtful design of teaming experiences and learning environments would be a productive focus for educators who are delivering project courses.

Conclusion and Recommendations

One of the primary conclusions of this research study is that academic self-confidence and self-efficacy do not change in straightforward ways over the course of the engineering students' program of study. Although students did experience significant increases in a number of engineering confidence or self-efficacy measures over the course, students in later years of the curriculum did not necessarily have higher confidence or self-efficacy in comparison to their younger peers. Coupled with our understanding of the relationship between self-confidence/self-efficacy and persistence, this suggests that we need a far more holistic approach to thinking about how students develop or retain engineering self-efficacy and self-confidence over the course of four years of the curriculum. In particular, the greater variability in the response of women students suggests that they may be more susceptible to the details of their academic environment beyond their specific project experiences and the tasks that they took on.

That absence of a steady increase in academic self-confidence or self-efficacy measures suggests that it may make less sense for educators to focus their efforts on increasing self-efficacy measured in absolute terms, but instead to focus on closing the gaps between students that result from gender or other demographics. One approach would be careful learning interventions, in the form of course structures that help all students engage in the full range of engineering tasks in hands-on, team-based project courses, such as individual projects as part of project courses, strict rotation of teaming roles, or asking students to articulate their learning goals for the course so they can take on related tasks. This would help obviate the gendered behavior of women taking on 'undesirable' tasks because 'someone has to', dividing themselves between many tasks, or bearing the emotional burden of being the 'nag' that has to 'push' the team. Senior courses are less likely to include specific instruction on how to work in teams, whereas our findings demonstrate that these interventions may be still needed as students progress.

This also suggests that educators need to continue to put energy and effort towards creating an academic culture that might address the increasingly gendered behavior over the four years of the curriculum. As noted in prior studies on self-efficacy, the effect of other contributors to self-efficacy (such as social affirmation and vicarious experiences) are clearly not inconsiderable for women (Cheryan, Plaut, Davies, & Steele, 2009; Hutchison-Green et al., 2008; Zeldin & Pajares, 2000); thus, educators may pay more attention to other components of self-efficacy beyond mastery experiences in order to better benefit female students and prevent loss of academic self-confidence or increasing stereotypically gendered behavior. For example, helping all students become aware of their implicit gender bias (Stein et al., 2014), would be expected to improve the types of social affirmation that female students might receive. Of course, aspects of this are outside of the direct purview of educators. In particular, internships and other engineering interactions may also involve experiences that erode engineering self-efficacy, such as lack of respect, inappropriate comments from male colleagues, and relegation to "shuffling papers" (Seron et al., 2016). These types of interactions will almost certainly affect how students interact with their engineering coursework and projects, and are likely to be contributors to increases in gendered behavior over the curriculum, as students return to campus from engineering internships.

In summary, our work reinforces prior research findings that project-based learning does increase students' engineering confidence and self-efficacy, but any benefits that are experienced may not be lasting, as there was little to no difference between first-year, sophomore and senior students' engineering confidence or self-efficacy measures. Although female students did have less confidence than male students in their first-year, these gaps closed by the sophomore year. There was no gendered task division in first-year or sophomore classes, while there was far more in the senior year; throughout every class level, however, female students described taking on emotional burdens and multiple tasks for their team. It is imperative that instructors continue to be mindful of implementation of project experiences, regardless of the class level of the students. This involves acknowledging that students may *not* become perceive themselves as becoming more confident engineers over the course of their studies, but assuring that the project experience can be beneficial as long as it is ensured that students practice and apply a wide range of engineering skills regardless of their class level or gender.

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Appendix A. Pre-Course Survey Confidence and Self-Efficacy Measures

Academic Self-Confidence

1. I am confident in my…

	Disagree strongly	Disagree moderately	Disagree a little	Neither agree nor disagree	Agree a little	Agree moderately	Agree strongly
Creative Thinking	○	○	○	○	○	○	○
Solving problems that can have multiple solutions	○	○	○	○	○	○	○
Social skills	○	○	○	○	○	○	○
Leadership ability	○	○	○	○	○	○	○
Public speaking ability	○	○	○	○	○	○	○
Math ability	○	○	○	○	○	○	○
Science ability	○	○	○	○	○	○	○
Communication skills	○	○	○	○	○	○	○
Ability to apply math and science principles in solving real world problems	○	○	○	○	○	○	○
Business ability	○	○	○	○	○	○	○
Ability to perform in teams	○	○	○	○	○	○	○
Critical thinking skills	○	○	○	○	○	○	○

2. How committed are you to completing an engineering degree?
   - ○ Not at all
   - ○ Slightly
   - ○ Moderately
   - ○ Strongly
   - ○ Very strongly

3. How confident are you in your ability to complete your engineering degree?
   - ○ Not at all
   - ○ Slightly
   - ○ Moderately
   - ○ Strongly
   - ○ Very strongly

Engineering Self-Efficacy

1. How much do you agree or disagree with the following statements?

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I can statistically model a process.	○	○	○	○	○
I can apply theoretical concepts to real-world problems.	○	○	○	○	○
I have data analysis skills.	○	○	○	○	○
I think practically.	○	○	○	○	○
I have written and oral communication skills.	○	○	○	○	○
I understand the relationship of theory to application.	○	○	○	○	○
I can develop/improve a product/system for manufacture of the product or implementation of the system.	○	○	○	○	○
I am a logical thinker.	○	○	○	○	○
I know different ways to create a design.	○	○	○	○	○
I can logically prove something works.	○	○	○	○	○
I use available tools and knowledge.	○	○	○	○	○
I have a broad technical knowledge base.	○	○	○	○	○
I can formulate and analyze a model of a problem.	○	○	○	○	○
I can apply theory to real problems.	○	○	○	○	○
I am a conceptual thinker.	○	○	○	○	○
I understand how parts work together to make the whole operate.	○	○	○	○	○
I have a technical understanding of fundamentals and the ability to use this knowledge.	○	○	○	○	○
I can summarize the key points of a technical problem with simple language.	○	○	○	○	○
I can do back-of-the-envelope calculations to show workability.	○	○	○	○	○
I can use a computer as a tool.	○	○	○	○	○
I have broad experiences with equipment.	○	○	○	○	○
I understand the theory behind how something works.	○	○	○	○	○
I know design concepts.	○	○	○	○	○
I understand the concepts behind how something works.	○	○	○	○	○
I can parse problems and develop a path to a solution.	○	○	○	○	○
I understand and can apply math concepts to a problem.	○	○	○	○	○
I have broad knowledge in fields beyond engineering.	○	○	○	○	○
I can communicate ideas and concepts to others.	○	○	○	○	○
I have the knowledge and technical skills to create mechanisms and devices.	○	○	○	○	○

Tinkering Self-Efficacy

1. How much do you agree or disagree with the following statements?

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I have more experience than knowledge.	○	○	○	○	○
I am persistent and willing to try new processes to get an invention to work.	○	○	○	○	○
I have a long history of tinkering on personal development projects.	○	○	○	○	○
I have the knowledge and technical skills to create mechanisms or devices.	○	○	○	○	○
I have spatial sense.	○	○	○	○	○
I consider solutions before taking things apart.	○	○	○	○	○
I am inquisitive.	○	○	○	○	○
I can think outside the box.	○	○	○	○	○
I can decipher mechanisms uncovered in tinkering.	○	○	○	○	○
I work well with my hands.	○	○	○	○	○
I try to understand how things work in order to fix problems.	○	○	○	○	○
I have a passion to create.	○	○	○	○	○
I understand technical drawings such as wiring diagrams.	○	○	○	○	○
I can troubleshoot technical problems.	○	○	○	○	○
I have deductive reasoning skills.	○	○	○	○	○
If I know enough about a technical system, I like to explore it.	○	○	○	○	○
I have imagination.	○	○	○	○	○
I like to take things apart to find out how they work.	○	○	○	○	○
I know what tools are available.	○	○	○	○	○
I am curious.	○	○	○	○	○
When I look at something I can imagine how it works.	○	○	○	○	○
I have creative abilities.	○	○	○	○	○
I take things apart and put them back together.	○	○	○	○	○
I have the persistence to complete a project.	○	○	○	○	○
I have mechanical intuition.	○	○	○	○	○
I have tinkering type hobbies.	○	○	○	○	○
I can visualize a product from the description of a problem.	○	○	○	○	○
I have experience using a range of tools.	○	○	○	○	○

Appendix B. Weekly Activity Log

1. Please enter your survey ID number.
2. How much time in TOTAL did you spend on this course this week (in hours)?
3. How much time this week did you spend in LECTURES associated with this course (in hours)?
4. How much time this week (in hours) did you spend on ORGANIZED ACTIVITY for this course that was not a lecture but also not project work? (For example, an in-class activity)
5. How much time this week did you spend on INDEPENDENT, NON-PROJECT work (in hours) such as working on a problem set, individually or with others?
6. How much time this week (in hours) did you spend working on a PROJECT, individually or as part of a team?
7. How much time did you spend on the following activities in the previous week (in minutes) (Please skip the activity if it does not apply to this project):
    - Researching and learning peoples' (users') needs
    - Other research
    - Individual brainstorming: finding inspirations, coming up with design goals
    - Individual brainstorming: exploring technical feasibility, integrating different ideas
    - Team brainstorming: finding inspirations, coming up with design goals
    - Team brainstorming: exploring technical feasibility, integrating different ideas
    - Creating a schedule for the project (Gantt chart)
    - Developing a work breakdown structure for the team
    - Reverse engineering (learning from professional or prior projects)
    - Sketching ideas in 2D
    - Building 3D sketch models
    - Using CAD (modeling, assembling, dynamic simulation, etc.)
    - Performing calculations related to the project
    - Working with a mechanical system (e.g. motor)
    - Working with electrical components (e.g. batteries)
    - Using a machine shop (either training or building)
    - Assembling a physical prototype
    - Improving aesthetics of a prototype
    - Testing an experimental prototype
    - Troubleshooting an experimental prototype
    - Preparing written materials to present or submit
    - Preparing visual materials to present or submit
    - Preparing the spoken component of a design review or presentation
    - Preparing audiovisual materials to present or submit
    - Participating in a design/midterm review
    - Managing a project budget
    - Purchasing materials or supplies
    - Managing supplies
    - Other project management
    - Documenting your process
    - Communicating with people outside your team
    - Taking notes during team meetings
    - Communicating with team members about the project
    - Motivating other team members
    - Cleaning/organizing workspace
    - Working individually on a written report
    - Working collaboratively on a written report
    - Compiling or editing a written report
    - Helping other students
    - Collaborating with other teams
8. Are there any other activities that you engaged in as a part of this course? If so, please describe the activity and tell us how long you spend engaged in it.
9. Looking back at your activities this week, can you tell us about why you chose to do each of them? Please be as brief or as detailed as you'd like.
10. Please reflect briefly on your activities this week: did anything unexpected happen? Do you feel good or bad about your progress? Is there anything else you would like to tell us about your activities this week?