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The Impact of Documenting Design Thinking, the Engineering Design Process Canvas, and Project Communication on Design Self-Efficacy of First-Year Students

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The Impact of Documenting Design Thinking, the Engineering Design Process Canvas, and Project Communication on Design Self-Efficacy of First-Year Students

Abstract

This complete evidence-based practice paper describes a study of three design interventions and a survey conducted of first-year engineering students at New York University to understand the impact on their design self-efficacy. The research question addressed in this study is whether there is an impact of documenting the design thinking process, the engineering design process, and project communication on students' level of self-efficacy to solve engineering design problems. And if so, to what extent did students find value in using the documentation activities for enhancing their engineering design capabilities? The aim of this study is to identify the best strategies for improving first-year students' design skills that will help them succeed in future design projects. Many tools have been developed to improve engineering design skills of first year students like design thinking exercises, the Engineering Design Canvas, and strategies for communicating ideas. The evidence-based practice described in this study consists of in-class exercises for each of these tools which include 1) an IDEO design thinking worksheet at the beginning of the project, 2) the Engineering Design Canvas at the middle of the project, and 3) the Heitmeier Catechism design communication strategies at the end of the project.

This study was conducted at New York University in the first-year multidisciplinary introductory engineering course General Engineering 1004 Introduction to Engineering and Design. Each semester, half of the 700 first-year students enroll in this course which requires all students to complete a multidisciplinary semester-long design project. The engineering design self-efficacy questionnaire developed in 2010 was used before and after to determine the impact of the three design exercises. In addition to the design self-efficacy instrument, open-ended questions were asked about students' feelings toward the design process. This study encompasses one semester with 300 first-year students in an introductory engineering course. The pre- and post-surveys take place before and after the first and last design intervention, respectively. Statistical analysis of the Likert responses to the engineering design self-efficacy questionnaire are used to compare before and after data to determine areas where the design interventions had the greatest impact. Other data collected included major, year, and the project type they completed to identify if other trends impacted their self-efficacy.

The survey results indicate that students' design self-efficacy had statistically significant improvements in all areas except for motivation to select a possible design. In general, the motivation dimension of self-efficacy had the smallest practically significant increase. However, student self-efficacy for confidence and success increased for each step of the engineering design process. The anxiety dimension saw a statistically and practically significant decrease for each engineering design step. While the causation is limited by the course design project being completed between the pre-survey and post-survey, the qualitative results indicate that many students found the design interventions to clarify aspects of each engineering design process step.

Introduction

Engineering design self-efficacy can be defined as the ability one assesses of themself to be effective and successful in the engineering design process. The engineering design process is made up of eight main parts: identifying a problem, researching the needs and constraints, developing solutions, selecting the best solution, building a prototype, testing the prototype, communicating the solution, and redesigning.

First–year engineering students do not have much experience regarding the eight steps of this process; thus, a study was conducted to measure first year engineering students' feelings regarding confidence, success, motivation, and anxiety within each step of the engineering design process [1]. Students are taught the design process in recitation and then apply the steps of the process through a cornerstone design project. Alongside the hands-on work, three design interventions were introduced throughout the semester to support understanding of the steps of design thinking, building a design canvas, and presenting a design pitch.

This project was completed with students registered for a first-year general engineering course that lasted the length of one semester. This course is designed to teach first year students basic engineering techniques like important software, critical thinking, and design, and how to present findings to a group of peers. Thus, the project is a part of the curriculum in that students are given project options and must use software, design techniques, and presentation skills to successfully complete the project following the steps of the engineering design process. Student teams were able to self-select between three different semester long project options.

Since two evaluations were done, the main purpose was to assess how engineering students' feelings of self-efficacy changes before a semester-long project versus after the fact regarding the engineering design process and determine whether documenting this process made an impact on feelings of confidence, success, motivation, and anxiety. Students were asked questions about these feelings regarding each step of the engineering design process as well as open-ended questions inquiring about feelings towards the project.

Background

Engineering and technology fields encompass complex problem-solving skills and one's ability in executing different ways of thinking when applying them to projects and tasks. The engineering design process itself instills problem-solving and real-world skill sets for those who wish to pursue these topics professionally. Developing these skills has been successful through the measurement of self-efficacy in first-year engineering courses and programs. Several studies investigate engineering design thinking, teaching, and learning which target strategies to increase engineers' capability to solve real-world issues by examining different teaching designs across institutions and the resources to support project-based learning [2]. Identifying the best pedagogical practices for improving project-based learning for engineering students is the desired outcome when trying to enhance design learning and self-efficacy [3,4].

Self-efficacy measurements aim to understand student levels of anxiety and increase levels of confidence when performing tasks professionally. Survey data was used to examine levels of achievement in various engineering and technology fields by observing the relationship between self-efficacy and confidence levels, project involvement, and design projects [3]. Researchers have found that focusing on project-based learning can enhance confidence and refine a skill set directed towards engineering fields. Feinaur's integration of innovation and entrepreneurship into first-year engineering courses focused on product-based innovation projects to develop a curriculum for students [5]. Students were successful in applying the techniques that they learned.

Assessing engineering design through projects has proven to increase first-year engineering students' self-efficacy [6]. This study included an in-class team design task supplemented by individual reflections. The exam on the other hand was an individual written assessment. Results concluded that the design task increased levels of self-efficacy more than the exam.

Conclusions about whether a student enrolled in first-year engineering courses even has the resources to succeed were highlighted by Caroline Baillie. After reviewing different course approaches in twelve countries and over seventy institutions a common approach was to develop the first-year introductory subject to aid orientation for students to feel and think like an engineer [7]. Prior research has emphasized the importance of offering project-based tasks for students to apply critical thinking skills.

The design canvas tool was used during this study to highlight behavior design and value towards the project. Research findings from the paper Development of a Design Canvas with Application to First Year and Capstone Design Courses discuss the relationship between creating a design canvas and project outcomes. The Business Model Canvas is a tool that can make distinctions between different design outcomes, representations of information, and the design process that follows. This study used Design Canvas from [8] with highlights of the three divisions of behavior, design, and value during the students' yearlong project. This study investigates the impact of the combined design project and canvas/design documentation tools on improving student design self-efficacy more than design projects alone.

Method

The Engineering Self-Efficacy survey was conducted a total of two times, once at the beginning of the Fall 2022 semester and once at the end; it took place during an attendance mandatory lecture for the first-year students.

The first survey asked feelings of confidence, success, motivation, and anxiety towards the engineering design process by ranking them one through ten (ten being a strong feeling) as well as feelings towards the completion of the project itself before the major semester long project had begun in early September. The second survey was conducted at the end of the semester and asked the same questions regarding confidence, success, motivation, and anxiety about the engineering design process, but then asked about feelings with the project having been completed. The students took the study online through Qualtrics, which kept the data anonymous. Once the surveys were completed, the data was analyzed and sorted by which numbers and answers to open-ended questions were most common and least common. Qualtrics gave percentages as well as the actual numbers of which numbers ranging from one to ten were chosen at a higher frequency than the others. The data for the same questions were then taken where the average and standard deviations for both were calculated and the results were graphed to show a visual comparison. Regarding the total number of responses, the first trial had a total of 261 whereas the second trial had a total of 232, and incomplete responses were discarded.

The individualized, open-ended questions were sorted through one by one. Trends in what the students were most anxious or excited about regarding the project were recorded and noted in frequency based on similar responses. The survey was divided into four Likert Scale sections: Confidence, Success, Motivation, and Anxiety. The responses were on a 1-10 basis, with one being the lowest degree in the respondent's abilities and ten being the highest. The structure of this section can be seen in Table 1.

Table 1: Likert Scale Statements from the Survey [1].
Conducted For Each Section (Confidence, Success, Motivation, And Anxiety).

Confidence, Success, Motivation, and Anxiety	
Statement	**No Confidence Fully Confident**
Conduct Engineering Design	1—2—3—4—5—6—7—8—9—10
Identify a Design Need	1—2—3—4—5—6—7—8—9—10
Research a Design Need	1—2—3—4—5—6—7—8—9—10
Develop Design Solutions	1—2—3—4—5—6—7—8—9—10
Select the Possible Design	1—2—3—4—5—6—7—8—9—10
Construct a Prototype	1—2—3—4—5—6—7—8—9—10
Evaluate and Test a Design	1—2—3—4—5—6—7—8—9—10
Communicate a Design	1—2—3—4—5—6—7—8—9—10
Redesign	1—2—3—4—5—6—7—8—9—10

In addition to the Likert Scale questions, open ended questions were asked to determine mindset prior to and after the semester and design projects were completed. These aided in determining if the worksheets influenced the respondents' engineering self-efficacy. These questions also aided in determining certain stressors and common themes throughout first year students. The pre-survey questions are shown in Table 2.

Table 2: Pre-Survey Qualitative Questions

What are you most excited about for your engineering design project?
What are you most anxious about for your engineering design project?
What resources do you wish you already had to help complete your project?

The following open-ended questions were asked after the completion of the first-year course. Included with the activity specific questions was a copy of the corresponding worksheet to aid memory. The post-survey questions are shown in Table 3.

Table 3: Post-Survey Qualitative Questions

What impact did the Design Thinking assignment (as seen above) in Milestone 1 have on your project?
What impact did the Design Canvas assignment (as seen above) in Milestone 2 have on your project?
What impact did the Design Pitch assignment (as seen above) in Milestone 3 have on your project?

Demographics questions were asked to determine the diversity of the respondent pool and to determine any potential bias in the responses. The questions in Table 4 were asked on both the pre and post surveys.

Table 4: Demographics Questions

Demographics Drop Down Questions
What is your major?
How many years have you been pursuing an engineering degree?
What is your semester-long design project?

Data Analysis

When determining the characteristics of the data given from both the pre and post survey, the mean, standard deviation, and frequency were determined. pre and post survey values were compared to each other to identify points of significant difference in one of the corresponding categories: confidence, success, motivation, and anxiety. While the original data pool for the pre survey consisted of 269 responses, after the omission of repeated or blank responses the survey results only consisted of 265 usable responses. Additionally, the initial data pool for the post survey consisted of 243 responses, which was reduced to 234 usable responses. After the elimination of the unusable data, both the pre and post survey results had a large enough sample size to determine if there was statistically significant difference on self-efficacy.

When determining if the results in each category (confidence, success, motivation, and analysis) were statistically significant, a t-test was conducted for each result. Comparison of the pre and post survey results on the normal distribution curves aided in determining which questions yielded significant results.

Confidence Analysis
Figure 1 below represents the frequency distribution of the responses from the Likert scale questions in the Confidence section pre and post survey. “Under-confident” corresponds to numbers 1-5 on the Likert scale and “Confident” corresponds to numbers 6-10.

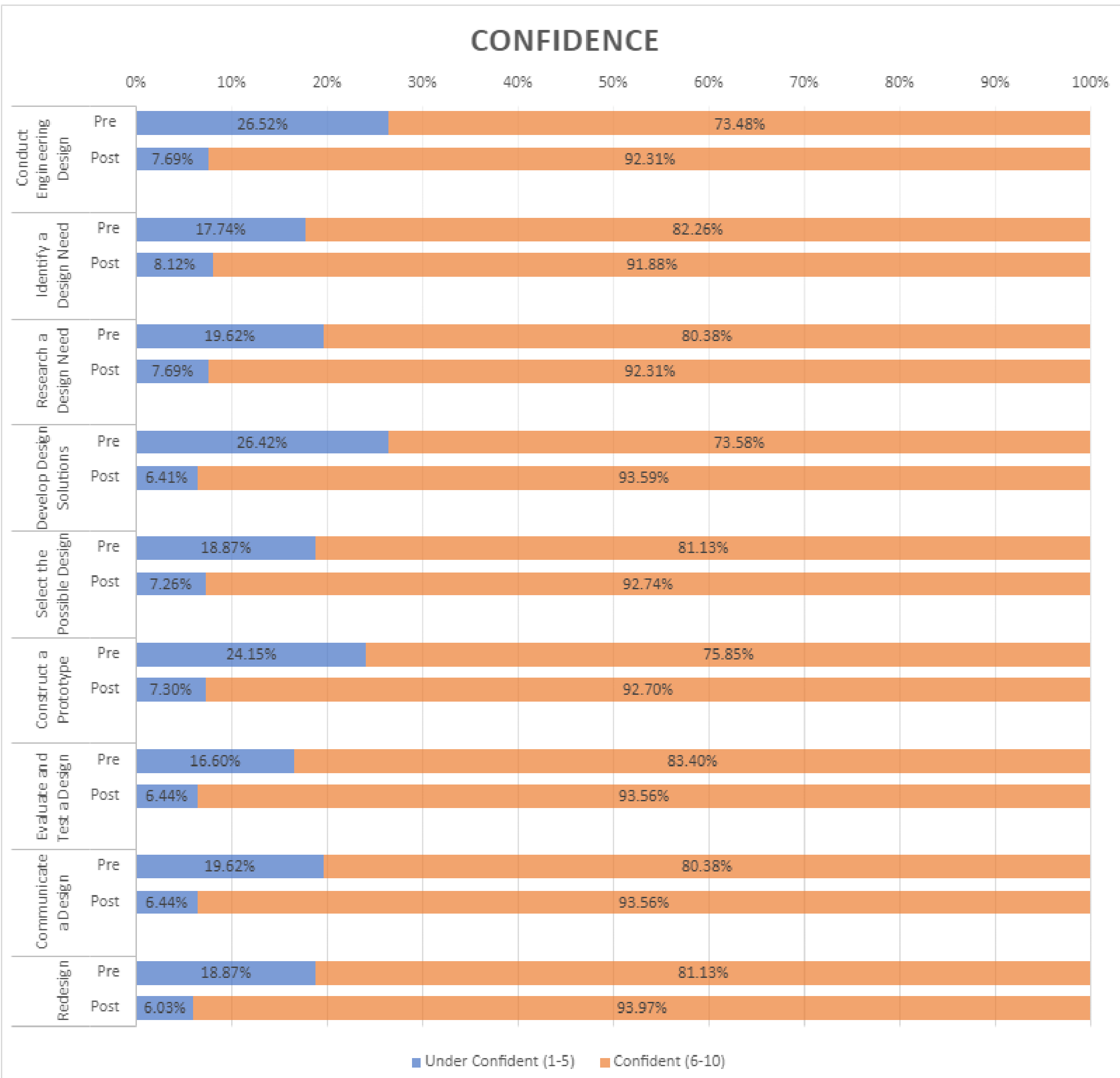

Figure 1: Stacked Frequency Data for Confidence Section Pre and Post Survey

Across all questions under the "confidence" category of self-efficacy the peak of the normal distribution increased in the post survey results compared to that of the pre survey. The average response for the pre and post survey can be viewed in Table 5. The difference in these averages was used to determine which question had the largest and smallest change. Bolded sections indicate the three questions with the largest average difference: "Conduct Engineering Design," "Conduct a Prototype," and "Redesign." All questions asked in this category had a p-value below 0.05, indicating statistically significant results at a 5% significance level.

Table 5: Comparison of Confidence Averages in Pre and Post Survey

Confidence Averages				
Statement	**Pre-Survey Average**	**Post-Survey Average**	**Difference**	**P-Score**
Conduct Engineering Design	***6.513***	***7.671***	***1.158***	***2.682E-14***
Identify a Design Need	6.906	7.919	1.013	7.256E-12
Research a Design Need	6.985	7.927	0.942	2.538E-09
Develop Design Solutions	6.683	7.799	1.116	9.645E-13
Select the Possible Design	6.947	7.705	0.758	8.238E-07
Construct a Prototype	***6.623***	***7.927***	***1.304***	***4.360E-15***
Evaluate and Test a Design	7.151	7.991	0.840	3.368E-08
Communicate a Design	7.230	8.236	1.006	1.302E-09
Redesign	***6.913***	***8.039***	***1.126***	***1.386E-12***

The largest increase can be seen in the normal distribution graph for degree of confidence in "Construct a Prototype" with the highest average difference of 1.304. The response of seven on the Likert scale had the highest frequency in the pre survey data, with 54 responses. The value of 8 had the highest frequency in the post survey data with 64 responses. "Conduct Engineering Design" and "Redesign" also had large average differences of 1.158 and 1.126, respectively. The response of seven on the Likert scale had the highest frequency in the "Conduct Engineering Design" pre survey data, with 80 responses. The value of 8 had the highest frequency in the "Conduct Engineering Design" post survey data, with 79 responses. The value of 8 on the Likert scale had the highest frequency for the "Redesign" pre and post survey, with 63 responses in the pre survey and 57 in the post survey.

The quantitative responses from the Likert scale test show that the overall confidence level across all categories increased for the respondent population. This indicates that the population feels more confidence regarding these steps in the design process at the end of the semester.

Success Analysis

Figure 2 below represents the frequency distribution of the responses from the Likert scale questions in the Success section pre and post survey.

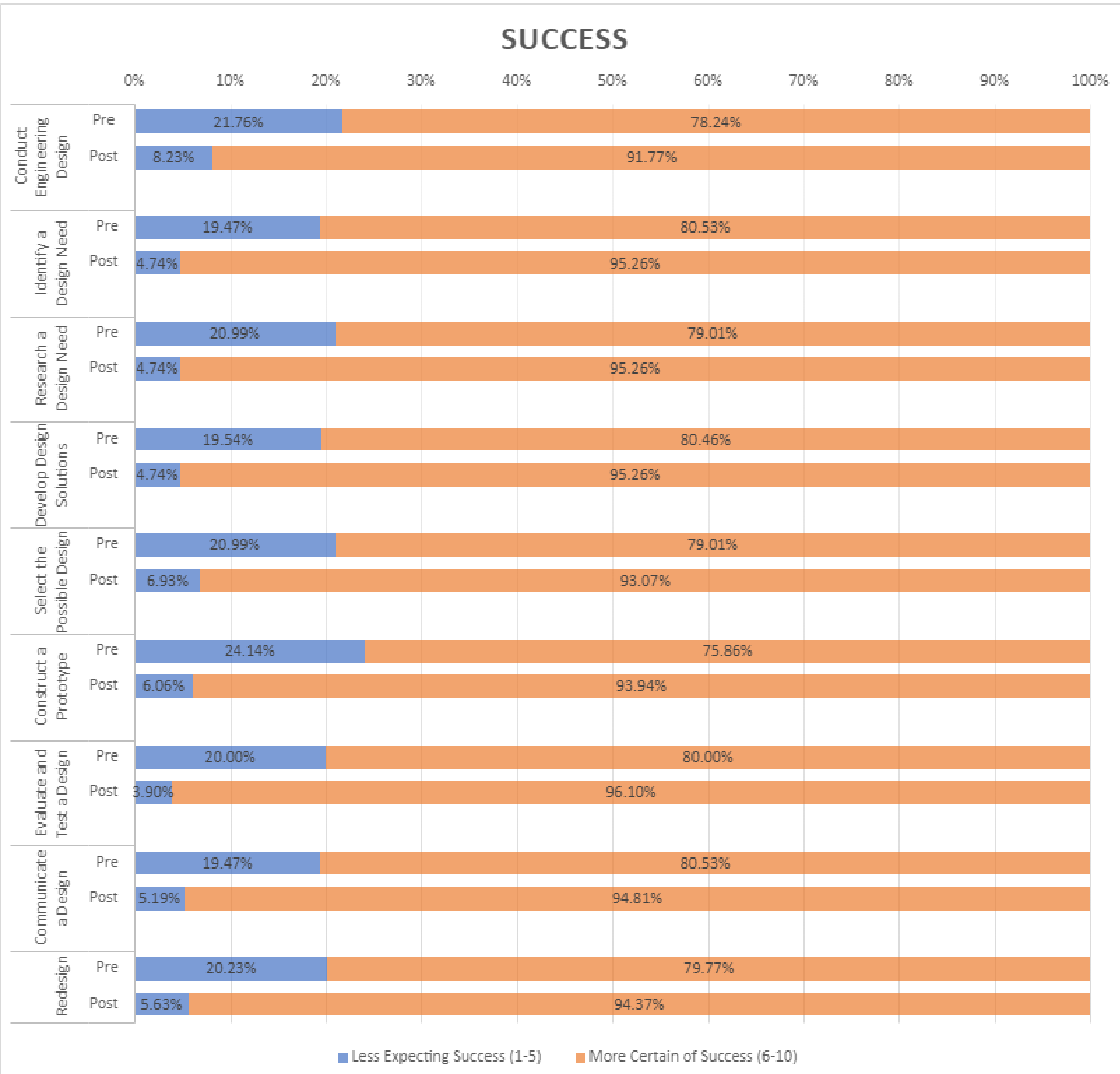

Figure 2: Stacked Frequency Data for Success Section Pre and Post Survey

The change in averages for pre and post survey regarding success is as shown in the table below. The change in averages is recorded in the difference category which was used to determine the highest and lowest changed questions. Across all questions under the "success" category of self-efficacy the peak of the normal distribution increased in the post survey results compared to that of the pre survey, which can be observed in the average differences between the pre and post surveys seen in Table 6 below. Bolded sections indicate the three questions with the largest average difference: “Research a Design Need,” “Develop Design Solutions,” and “Construct a Prototype.” All questions asked in this category had a p-value below 0.05, indicating statistically significant results at a 5% significance level.

Table 6: Comparison of Success averages in Pre and Post Survey

Success Averages				
Statement	**Pre-Survey Average**	**Post-Survey Average**	**Difference**	**P-Score**
Conduct Engineering Design	6.828	7.727	0.899	4.468E-09
Identify a Design Need	6.969	7.905	0.936	7.078E-10
Research a Design Need	**6.954**	**8.017**	**1.063**	**7.078E-10**
Develop Design Solutions	**6.866**	**7.922**	**1.057**	**1.188E-12**
Select the Possible Design	6.981	7.879	0.898	2.456E-09
Construct a Prototype	**6.739**	**7.996**	**1.256**	**9.428E-15**
Evaluate and Test a Design	7.108	8.087	0.979	1.629E-10
Communicate a Design	7.282	8.147	0.865	5.511E-08
Redesign	7.004	8.026	1.022	1.276E-11

The largest increase in average for success was Degree of Success for “Construct a prototype.” The difference recorded was a 1.256 increase, from an average of 6.739 to 7.996. The pre survey data indicated the highest frequency of responses tied at 7 and 8 with 53 responses in each of them. In the post survey data, the highest frequency of responses was eight. The frequency under the 9 category increased by 78% going from 27 in the pre survey to 48 in the post. “Research a Design Need” and “Develop Design Solutions” also had large average differences of 1.063 and 1.057, respectively. The value of 8 on the Likert scale had the highest frequency for the “Research a Design Need” pre and post survey, with 67 responses in the pre survey and 83 in the post survey. The response of seven on the Likert scale had the highest frequency in the “Develop Design Solutions” pre survey data, with 59 responses. The value of 8 had the highest frequency in the “Develop Design Solutions” post survey data, with 86 responses.

The quantitative responses from the Likert scale test show that the overall degree of success across all categories increased for the respondent population. This indicates that the population feels more confidence in their success regarding these steps in the design process at the end of the semester.

Motivation Analysis

Figure 3 below represents the frequency distribution of the responses from the Likert scale questions in the Motivation section pre and post survey.

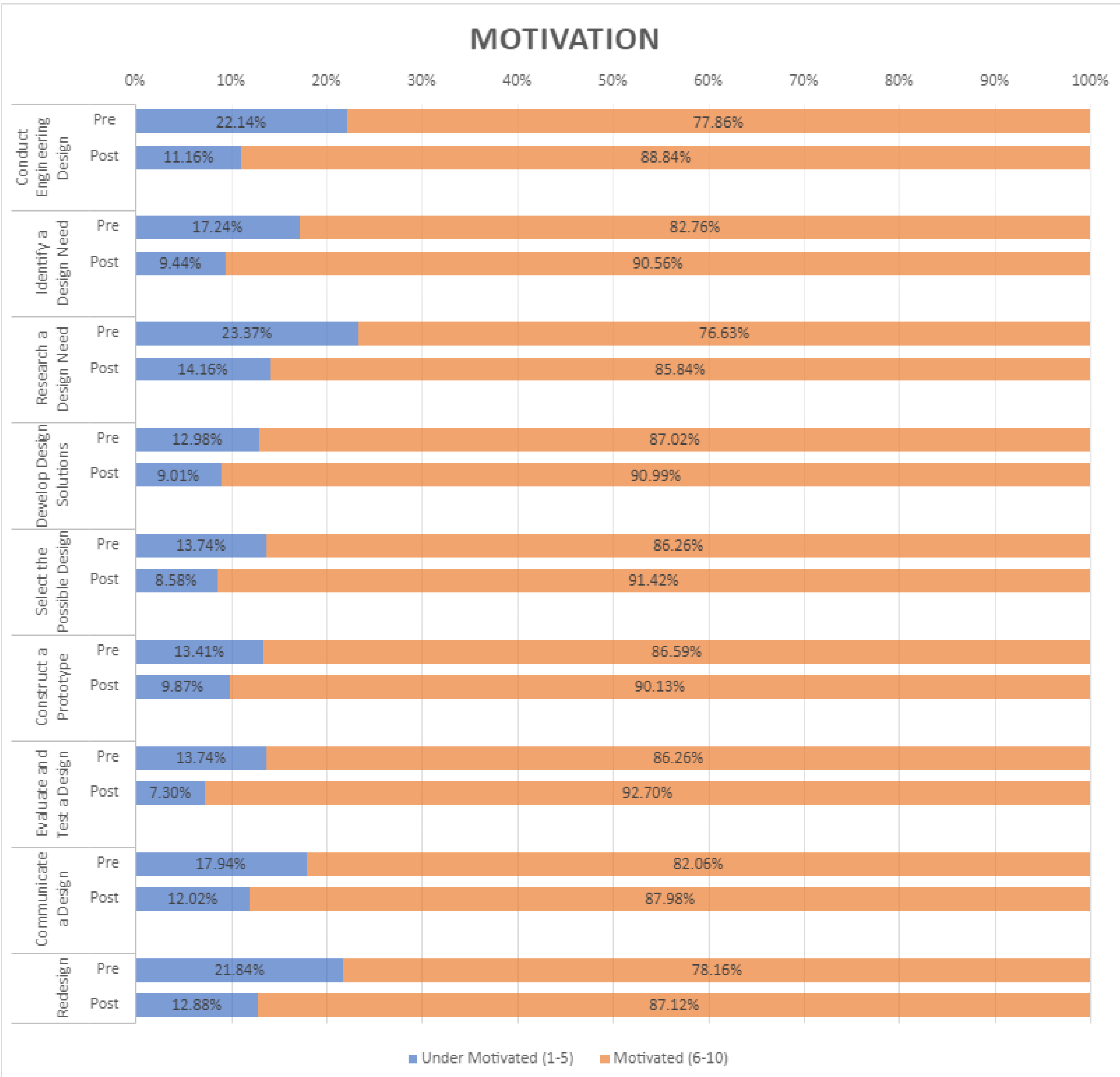

Figure 3: Stacked Frequency Data for Motivation Section Pre and Post Survey

The change in averages for pre and post surveys regarding motivation is as shown in Table 7 below. The change in averages is recorded in the difference category which was used to determine the highest and lowest changed questions. Across all questions under the "motivation" category of self-efficacy the peak of the normal distribution increased in the post survey results compared to that of the pre survey, which can be observed in the average differences between the pre and post surveys seen in the table below. However, the changes in this category are notably smaller than those observed in the other categories: with the average difference in the "motivation" category ranging from 0.200 to 0.618, while the other categories average a range of 0.816 to 1.270. Bolded sections indicate the three questions with the largest average difference: "Conduct Engineering Design," "Research a Design Need," and "Redesign." Most questions asked in this category had a p value above 0.05, indicating statistically significant results in this category. However, "Select the Possible Design" yielded a p value of 0.125, above the 0.05 threshold, indicating that this result was not statistically significant. This question also had the lowest average difference of 0.200.

Table 7: Comparison of Motivation averages in Pre and Post Survey

Motivation Averages				
Statement	**Pre-Survey Average**	**Post-Survey Average**	**Difference**	**P-Score**
Conduct Engineering Design	7.229	7.798	0.569	0.001
Identify a Design Need	7.272	7.725	0.453	0.004
Research a Design Need	6.996	7.614	0.618	0.001
Develop Design Solutions	7.592	7.918	0.327	0.025
Select the Possible Design	7.748	7.948	0.200	0.125*
Construct a Prototype	7.762	8.077	0.315	0.038
Evaluate and Test a Design	7.695	8.099	0.404	0.011
Communicate a Design	7.469	7.841	0.372	0.022
Redesign	7.119	7.687	0.568	0.002

* Not statistically significant at a 5% significance level

The largest increase in average for success was Degree of Motivation in "Research a Design Need." The difference recorded was a 0.618 increase, from an average of 6.996 to 7.614. The pre survey data indicated the highest frequency of responses at 8 with 50 responses. In the post survey data, the highest frequency of responses was at 8, with 47 responses. Although the number of eight responses decreased, the number of nine responses increased by a greater amount. "Conduct Engineering Design" and "Redesign" also had large average differences of 0.569 and 0.568, respectively. The value of 8 on the Likert scale had the highest frequency for the "Conduct Engineering Design" pre and post survey, with 54 responses in the pre survey and 63 in the post survey. The value of 8 on the Likert scale had the highest frequency for the "Redesign" pre and post survey, with 60 responses in the pre survey and 59 in the post survey.

The quantitative responses from the Likert scale test show that the overall degree of motivation across all categories increased for the respondent population. This indicates that the population feels more motivated regarding these steps in the design process at the end of the semester. However, the average differences were notably smaller in this section indicating that this was an area of weakness in the respondent population regarding confidence in their motivation in the design process.

Anxiety Analysis
Figure 4 below represents the frequency distribution of the responses from the Likert scale questions in the Anxiety section pre and post survey.

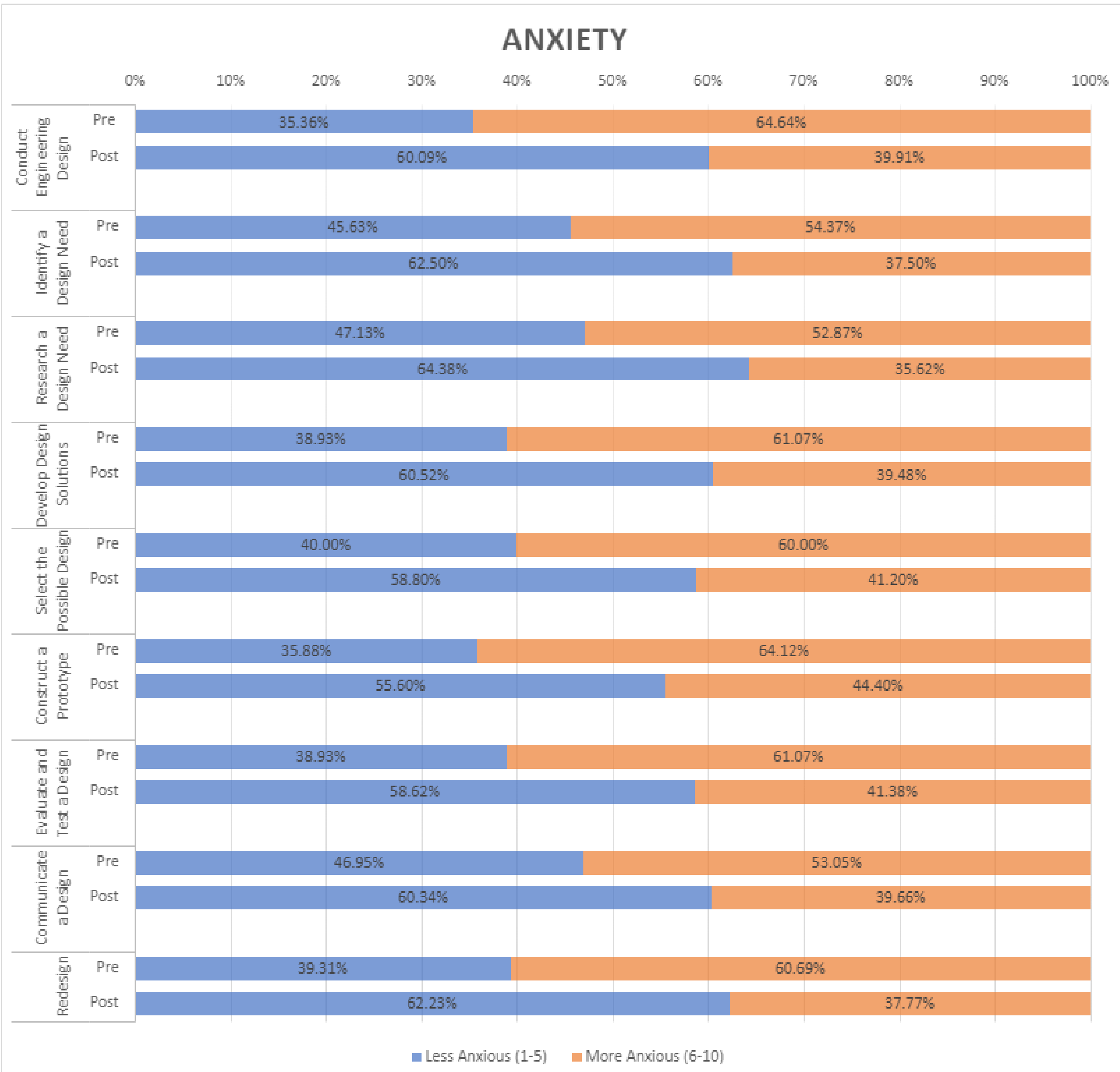

Figure 4: Stacked Frequency Data for Anxiety Section Pre and Post Survey

The change in averages for pre and post surveys regarding anxiety is as shown in the table below. The change in averages is recorded in the difference category which was used to determine the highest and lowest changed questions. Across all questions under the "anxiety" category of self-efficacy the peak of the normal distribution decreased in the post survey results compared to that of the pre survey, which can be observed in the average differences between the pre and post surveys seen in the table below. Out of the four sections surveyed in this study, this was the only section with negative differences, indicating an overall decrease in anxiety across all questions asked. Bolded sections indicate the three questions with the largest average difference: "Conduct Engineering Design," "Develop Design Solutions," and "Construct a Prototype." All questions asked in this category had a p-value below 0.05, indicating statistically significant results at a 5% significance level.

Table 8: Comparison of Anxiety averages in Pre and Post Survey

Anxiety Averages				
Statement	**Pre-Survey Average**	**Post-Survey Average**	**Difference**	**P-Score**
Conduct Engineering Design	6.331	5.082	-1.249	2.669E-07
Identify a Design Need	5.753	4.754	-0.999	3.180E-05
Research a Design Need	5.705	4.725	-0.980	7.488E-05
Develop Design Solutions	6.164	4.961	-1.203	6.457E-07
Select the Possible Design	6.188	5.052	-1.137	5.434E-06
Construct a Prototype	6.466	5.134	-1.332	1.046E-07
Evaluate and Test a Design	6.073	5.022	-1.051	2.703E-05
Communicate a Design	5.584	4.759	-0.825	0.001
Redesign	6.088	4.918	-1.169	2.230E-06

The largest decrease in average for success was Degree of Anxiety in "Construct a Prototype." The difference recorded was a 1.332 decrease, from an average of 6.466 to 5.052. The pre survey data indicated the highest frequency of responses at 10 with 44 responses. In the post survey data, the highest frequency of responses was at 1, with 30 responses. "Conduct Engineering Design" and "Develop Design Solutions" also had large average differences of -1.249 and -1.203 respectively. The response of eight on the Likert scale had the highest frequency in the "Conduct Engineering Design" pre survey data, with 49 responses. The value of 3 had the highest frequency in the "Conduct Engineering Design" post survey data, with 34 responses. The value of 8 on the Likert scale had the highest frequency for the "Develop Design Solutions" pre survey, with 49 responses. The highest frequency response in the "Develop Design Solutions" post survey was the value of 3, with 31 responses.

Qualitative Analysis

The responses to the open-ended survey questions provide insight into the ways the design activities might have influenced the motivation, success, anxiety, and confidence of the respondents throughout the semester. When looking through the most sentiments present in the most student responses, they can be grouped into one of five categories, as seen below in Table 9.

Table 9: Select Student Free Responses to questions about impact of engineering design assignments grouped by similarity of responses.

Type of Impact	Design Thinking Assignment	Design Canvas Assignment	Design Pitch Assignment
Clarity and Direction	It helped us **narrow down** the scope of our project. **Clarify** the initial design. This helped create a **structure** and obtain clarity on the purpose of our project.	It helped us **organize** our **thoughts** on our projects. Helped **clarify** specific aspects of the project. It gave us a **more clear plan**	This assignment allowed me to **reorient** the way I viewed the project overall, which led us in a new **direction**. It helped us **organize** our thoughts for the milestone presentations and how we are going to **frame** the purpose of our project.
Brainstorming	Helped **brainstorm** and come up with the best possible project to do. Allowed us to **filter out our ideas** and try and have more of a structure to **brainstorm** ideas	It allowed for **brainstorming** and different design ideas. It allowed for **brainstorming** and different design ideas	Helped **brainstorm ideas** for future presentations. It helped us **brainstorm** our marketing for the prototype.
Purpose and Confidence in Project	It **identified the goal** of our project and why we want to **complete it**. It gave us a fuller **understanding** of our project and its **purpose**	Help us be more **confident** on our design. The Design Canvas assignment provided a challenge as to how we would explain our project to other people, this will solidify our idea of the **purpose** and **usefulness** of our design.	This helped us to finally **develop the purpose of the project**, and how could we improve our design It helped contextualize the **purpose** of the project

Communicating Design Ideas	It just helped to improve our **communication.** How to **communicate** the value of my design	The Design Canvas assignment provided a challenge as to how we would **explain our project** to other people, this will solidify our idea of the **purpose and usefulness of our design**.	Helped understand how to **pitch** the product to investors and **explain its relevance.** Help **simplify** the project's function to make **communicating** the design easier.
Improvement of Project (identifying target audience, problems and solutions)	Helps to **define problems and potential solutions** for design It helped our team to build a **foundation** for our project and start thinking about its **target audience** It helped us **reevaluate** how we felt about the project so far and get on the same page about **recurring issues** we'd been facing and how to **deal with them**	This worksheet helps us find out who are the people that will benefit from the project we were making and **who is our audience.** It gave us a fuller understanding of our project and its **purpose**	It helped us learn how to **promote our project** by promoting its **benefits and advantages**. How to **improve** the product as much as possible Help us to know how to **improve**

When looking at the responses to the open-ended question in the pre-survey, "What are you most anxious about for your engineering project?" The most cited responses were related to "time/deadlines" and "completion of the project.," suggesting most students felt anxious about their confidence in completing a project within the period of a semester. The responses to the post-survey provide ideas about the ways the designs thinking activities might have helped reduce anxiety, increase confidence, and improve the student projects overall.

As seen in the table above, all three design thinking activities provided students with a sense of clarity and direction as well as the ability to brainstorm ideas. These alleviated certain anxieties that students had with regards to starting and completing the project. This result also supports the quantitative results as "Conduct an Engineering Design" and "Construct a Prototype" displayed the most significant decrease in the anxiety category, suggesting that the design thinking activities helped students feel more confident in producing design ideas and starting the process of constructing a prototype.

In addition to confidence with starting the process, the students' responses suggest that the activities also provided them with a sense of purpose and confidence in the importance of the design and the project. Having a view of why the project is important beyond the class could have made students more confident in their decision making, and more motivated in general to complete the project. In both the motivation and confidence category, "Redesign" had the most significant increase, suggesting that an understanding of the purpose of the design is related to a willingness to make changes and improve the project altogether. Student responses such as "This helped us to finally **develop the purpose of the project**, and how could we improve our design" are an example of this.

Students also found the activities helpful in improving and considering multiple aspects of their projects, ranging from identifying target audiences, solving problems, and producing solutions. In the success category, "Develop Design Solutions" and "Construct a Prototype" had the most significant increase, all the highlighted factors above, as well as the ability to improve and consider multiple aspects could be linked to increases in overall success. Responses such as "This helped us improve," and "This activity allowed us to define problems and solutions," provide evidence for this improvement.

Given this, it is also important to acknowledge responses of students that suggested the design activities had "little to no impact" or that they were given at a time when they had already made enough progress on their projects. While these responses do not represent the majority, they still provide improvements to the design activities and suggest that while they were impactful, there is still room for improvement.

Conclusion

This paper provides insight on the impact of design interventions on the design self-efficacy of first-year engineering students. Quantitative and qualitative results from a pre and post survey conducted in a first-year introductory engineering course were used to study the impact of design interventions on the students' self-efficacy. This research indicates conducting engineering design, developing possible solutions, and constructing a prototype would increase students' success and motivation while reducing their anxiety.

The data from the surveys was categorized into four Likert scale sections: Motivation, Success, Confidence, and Anxiety. Each of these categories showed an increase on the Likert scale in the post-survey suggesting the respondents on average felt more motivated, confident, and successful. The post-survey responses towards anxiety decreased indicating students were less anxious about their projects. The open-ended survey questions suggest that the design activities provided students with clarity and direction, giving them confidence in the importance of the project, and allowing them to make improvements. These responses suggest that the design interventions might have been related to the increases in motivation, success, confidence, and anxiety; however, there is no way of ensuring that the design interventions were the most significant factor affecting students' motivation, success, confidence, and anxiety.

The results suggest the implementation of design interventions could be a useful consideration for similar first-year introductions. The limitations of this study include the lack of a control semester before the interventions were introduced. Future research on additional courses performing the pre and post surveys in a semester with and without the design intervention would help to identify the direct impact of the design interventions.

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