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CHANGE IN PEER EFFICACY OF SENIOR DESIGN STUDENTS DURING A DESIGN PROJECT: A CASE STUDY

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Abstract

Engineering students gain knowledge regarding mechanics, thermodynamics, and other topics throughout their undergraduate curriculums. However, often their instruction regarding design is not presented until students' senior years. The purpose of this study is to gain an understanding of senior design students' opinions of their peers, specifically in regards to engineering efficacy. The data necessary for this evaluation was collected using a survey tool. Survey responses were solicited twice over the course of a semester in the pre-capstone senior design course. The initial set of responses was captured on the sixth week of the semester, and the second set of responses was captured during the final week of class (week fifteen). The results from both surveys collected were analyzed to evaluate the change in responses over the course of the semester. The results indicate that in general, the student perception of their peers improved regarding their technical knowledge and creativity, however their perception regarding project skills and social impact changed negatively.

Keywords: Collaborative design, Case study, Design education, Teamwork, Social responsibility

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1 MOTIVATION TO RESEARCH PEER EFFICACY OF UNDERGRADUATE ENGINEERING STUDENTS

In the US engineering design is often taught in two phases, first the process and methods and then a capstone experience (Ohland and Summers, 2007; Marin et al., 1999; Todd et al., 1993; Hyman, 2001). Specifically, at the university studied, the first phase is comprised of a senior design course that provides students lectures on the systematic engineering design process (Patel et al., 2016; Summers et al., 2014; Joshi and Summers, 2015). A significant portion of the class grade is a semester long project, typically a service project where student teams design and build experimental equipment for local elementary school classrooms. The equipment should support experiments to teach elementary school students about various scientific principals from forces and waves to agriculture, manufacturing, or power generation depending on grade level curriculum. Student teams range in size from five to six. The teams are assigned in the third week of the semester and have until the final week of class (week fifteen) to design and fabricate a device for their assigned elementary school classroom. This project provides students the opportunity to directly apply the design process learned in class in a collaborative environment. Teams have biweekly design reviews with the professor and graduate teaching assistant. Feedback is provided on project management, design process, technical merit, and professional communication. For most students, this is the first time they have had the opportunity to work on design teams for an extended hands-on design project.

The second phase of the design courses is the capstone design course (Joshi et al., 2011; Powers and Summers, 2009; Maier et al., 2010). This course is comprised entirely of project experience and effectively serves as an “exit exam” for the undergraduate students. Teams of four to six students work on industry sponsored design projects for the entire sixteen-week semester. The capstone course provides students with experience working on a typical engineering project found in a manufacturing environment prior to graduation with weekly feedback from an advisory committee of faculty and periodic design reviews with the industry sponsor.

The focus of the study presented in this paper is to evaluate students' perceptions of their peers' engineering abilities. This study was performed in the pre-capstone course and the data was collected using a survey tool. The survey was a course assignment in week six and sixteen of the course. This corresponds with the beginning of the service design project and its conclusion. The two different time periods provided an opportunity to analyze the changes in students' perceptions of their peers' engineering abilities.

2 BACKGROUND ON STUDENT DESIGN TEAM RESEARCH

Design projects are often times ambiguous and complex, requiring collaboration amongst engineers and other professionals to be solved (Ostergaard and Summers, 2003; Pahl and Beitz, 2013; Ullman, 2010). Systematic approaches to engineering design provide engineers with a basic process to use while solving these complicated design problems. Engineers using this process begin by defining the problem and creating conceptual solutions. As the problem-product couple matures, the product solutions are evaluated, filtered, selected, and expanded. Finally, details are added and completed products are tested and manufactured (Pahl et al., 2007; Ertas and Jones, 1993; Ullman, 2010).

Engineering curriculums offer students numerous opportunities to learn technical skills, systematic analysis methods, and how to use computers as a tool to solve problems. However, some engineering programs do not offer classes that teach some of the softer skills required in industry such as leadership and communication (Kumar and Hsiao, 2007). Some programs previously identified this gap and created a minor for engineering students that provides students an option to take classes that teach communication and project management (Seat et al., 2001). Essentially, industry is requiring students to know more than just technical engineering skills in order to secure a job after graduation. This study presented in this paper investigates students’ perceptions of their peers’ abilities to work in teams, communicate, and problem solve, all crucial skills to post graduation success.

There have been numerous studies previously performed on student design teams. These studies range from identifying the leader’s position in the social structure to inspire creativity (Kratzer et al., 2008) to observing the effects of diversity within student design teams (Hanus and Russell, 2007; Kress and

Schar, 2011; Ibn-E-Hassan et al., 2014). For instance, one study observed team member's functional behaviors throughout the course of a capstone design course and demonstrated that the behaviors each team member performs changes as the project matures (Born and Schmidt, 2016). Design team communication methods have been studied to and demonstrate that face to face communication is the most effective means of sharing design concepts and solutions during design reviews (Ostergaard et al., 2007). Basic functional leadership theory identifies both task oriented and interpersonal behaviors are crucial to project and team success (Morgeson et al., 2010; Derue et al., 2011). Task oriented leadership behaviors include setting goals, ensuring team members are working to standards, and coordinating resources for team members. Leadership studies within student design teams have concluded that student leaders more frequently demonstrated task oriented leadership behaviors than interpersonal leadership behaviors (Palmer and Summers, 2011).

The focus of many of these studies is to evaluate students' self-efficacy and then from the evaluation identify what influences self-efficacy and promote self-efficacy in undergraduate students (Hutchison, et al. 2006). Self-efficacy studies have also been performed in order to predict student success in academia and after graduation in industry (Lent et al., 1986, 1984, 2008). Tools have been established to measure students self-efficacy in engineering design such as the survey instrument of (Carberry et al., 2010). Functional leadership skills are highly desirable in industry, but measuring and assessing these skills is limited to self-efficacy and faculty observations. As an alternative, students' perceptions of their peers' functional leadership behaviors were observed in this study.

This study diverts from the self-efficacy studies presented, because the focus is no longer on the students' view of themselves, but their views of their peers' abilities to produce a desired result. Thus, this study focuses on understanding peer efficacy amongst engineering students. While the specific focus of this study is on senior students' perceptions of their peers' engineering knowledge, technical skills, and collaboration skills. Peer efficacy was investigated in order to gain a new perspective into how engineering students perceive their peers' skills and possibly will reveal a more objective efficacy evaluation than self-efficacy.

3 EXPERIMENT DESIGN

The objective of this research is to investigate the change in student perception of their peers, specifically, their engineering design efficacy. As a result, it is necessary to understand the student perceptions at the beginning of the semester as well as at the end of the semester.

3.1 Peer Efficacy Survey

In order to capture the student perceptions, a survey used in previous research to capture the change in self-efficacy as a result of an entrepreneurship course was adopted (Zapata-ramos and Perez-vargas, 2016). Statements 1-29 in Table 1 are adopted directly from the self-efficacy survey (Zapata-ramos and Perez-vargas, 2016), while the remaining ten prompts are geared directly towards student perceptions of engineering and the impact of their work as engineers. It should be noted that although the survey items are directly adopted from prior work, the variable measured in this case is peer-efficacy rather than self-efficacy. Therefore, the results of these survey items are not expected to match the results seen in the previous study and will not be compared.

There are two questions relating to the empathy or ability to understand and relate to others (white shading). Two statements are focused on assessing the knowledge of the peers, both technical and engineering (green shading). Twelve statements are defined to evaluate the innovative capacity to think in new paradigms while generating novel ideas (blue shading). Two additional questions are focused on the creativity of generating new ideas using previous knowledge (orange shading). Four questions are evaluating the decision making, project management, and project evaluation through project skills (gray shading). Students' ability to create and interact with physical systems are assessed through five separate questions (pink shading). The teams' ability to communicate new ideas, justify these solutions, and to report progress is anchored through four questions (red shading). Finally, the social impact of the students is studied as the interest in evaluating and furthering humanitarian engineering and found in eight statements (yellow shading).

Table 1. Survey Prompts Provided to Students

#	Statement	#	Statement
1[1]	My team members understand the needs of people by listening to their stories.	13[5]	My team members are able to set clear goals for a project.
8[1]	My team members consider the viewpoints of others/stakeholders.	24[5]	My team members are able make a decision based on available evidence and opinions.
2[2]	My team members find connections between different fields of knowledge.	14[6]	My team members are able to troubleshoot problems.
3[2]	My team members seek out information from other disciplines to inform my own.	18[6]	My team members learn by observing how things in the world work.
4[3]	My team members are able to identify opportunities for new products and/or processes.	27[6]	My team members are able to model a new idea or solution.
5[3]	My team members question practices that others think are satisfactory.	29[6]	My team members are able to explore and visualize how things work.
7[3]	My team members are able to make risky choices to explore a new idea.	31[6]	My team members do engineering related projects outside of class.
11[3]	My team members are able to envision how things can be better.	16[7]	My team members are able to communicate ideas clearly to others.
12[3]	My team members are able to do things in an original way.	17[7]	My team members provide compelling stories to share ideas.
15[3]	My team members stay informed about new ideas (products, services, processes, etc.) in my field.	23[7]	My team members share what they have learned in an engaging and realistic way.
19[3]	My team members are able to solve most problems if My team members invest the necessary effort.	30[7]	My team members enjoy reading about engineering.
20[3]	My team members are resourceful when handling an unforeseen situation.	32[8]	My team members consider engineering to be fun.
21[3]	My team members are able to suggest new ways to achieve goals or objectives.	33[8]	My team members see engineering as a means to improve quality of life.
22[3]	My team members test new ideas and approaches to a problem.	34[8]	My team members are interested in improving engineering education for K-12 students.
25[3]	My team members are able to relate seemingly unrelated ideas to each other.	35[8]	My team members are aware of contemporary issues in engineering.
28[3]	My team members find new uses for existing methods or tools.	36[8]	My team members pursue engineering to make a positive impact on the world.
6[4]	My team members are able to come up with imaginative solutions.	37[8]	My team members pursue engineering to make a positive social impact.
26[4]	My team members think of new and creative ideas.	38[8]	My team members pursue engineering to make a positive economic impact.
9[5]	My team members are able to evaluate the success of a new idea.	39[8]	My team members pursue engineering to make a positive environmental impact.
10[5]	My team members are able to apply lessons from similar situations to a current problem of interest.		
1 – Empathy, 2 – Knowledge, 3 – Innovative, 4 – Creative, 5 – Project Skills, 6 – Tactile/Visual, 7 – Communication, 8 – Social Impact			

3.2 Participants

Participants varied in age between 20-30 years old with most being between 21-22 years old. Most students (around 90%) have at least one semester working experience through an internship or cooperative education (co-ops) opportunity with an industry sponsor. Further, all the students are mechanical engineering seniors at Clemson University and have taken at least 90 course credit hours, with a minimum of 43 hours being engineering credits. Each participant was assigned to a design team near the beginning of the course to complete their team project. The given challenge was to design and build experimental equipment for a local elementary or middle school with a specific teacher and class as a customer. Teams were assigned based on individual resumes including working experience, courses taken, and personal skills using CATME software support[1]. There was a total of 128 individuals in the course divided into 21 teams, each team consisting of between six and seven members.

The participants for this research were Fall 2016 pre-capstone design students at Clemson University. These participants were selected because the course structure allowed for individuals to focus on their specific teammates instead of their classmates. In addition to the project, the students were expected to complete individual assignments and reflective essays on the different design tools taught in the class. This allowed for a non-intrusive integration of the survey instruments used for data collection. The students were considered for this research because they were expected to have had experiences working with other engineers through their internships, co-ops, and prior courses taken. Moreover, by completion of the course the students are roughly four months away from entering the workforce as novice engineers.

3.3 Experiment Variables

The survey prompts were presented to the students in paper format with a 100mm line adjacent to the survey prompt where the students were expected to mark their level of agreement ranging from “strongly disagree” to “strongly agree” (Wewers and Lowe, 1990; Thimmaiah et al., 2017). An example of a survey prompt as given to the students can be seen in Figure 1.

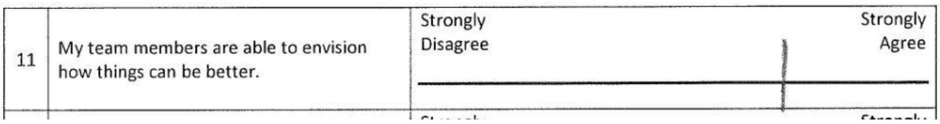

Figure 1. Example of A Student’s Response to Survey Prompts

As shown in Figure 1, the students were asked to use a vertical line to indicate their level of agreement on the horizontal line adjacent to the survey item. As mentioned earlier, this survey was provided to the students towards the beginning of the semester as well as towards the end of the semester. Therefore, the change in student agreement level was to be used as a metric of change in student perception of their team members engineering design efficacy. Additionally, the survey items were grouped into various categories which can be used to explore student perception in more detail, as well as identify the change in perception within these categories, as well as between groups.

3.4 Data Collection and Analysis

The survey responses collected from the students were grouped by section. The traditional method to measuring the level of agreement is to measure the distance from the left edge of the line to the tick mark. These values can be used to calculate a percent agreement for each statement. However, due to the number of responses totaling over 9000, a Matlab based image processing algorithm was used to generate the level of agreement. Each survey was scanned and the response area for each survey was cropped and saved. Next, the horizontal line and the vertical tick marks were identified. Subsequently, the distance to the tick mark from the start of the horizontal line was measured in number of pixels. Finally, an agreement percentage was calculated using the total length of the horizontal line and the distance to the tick mark.

Executing the algorithm generates agreement level matrices for each set of surveys: Section 1 and Section 2, early semester and late semester. These matrices contain the level of agreement provided by each student for each statement. This data was then analyzed for overall mean, as well as the change in agreement level from early semester to late semester. A two-sample t-test was conducted for each survey statement to determine of there was a significant change in the mean response for each of the survey items.

4 RESULTS AND DISCUSSION

Survey categories are used to assist in analyzing what the students thought of their peers with respect to each of the categories listed as well as how the peer efficacy results changed over time. Results are divided to show early semester results and the change over time in responses from the students.

[1] http://info.catme.org/ accessed January 3, 2017

4.1 Early Semester Response Distribution

The surveys collected in week 6 of the semester long team project were analyzed for the mean level of agreement on each survey item. Table 2 shows the mean response of the agreement for all the students surveyed. The individual agreement responses ranged from as low as 1% to a maximum of 100% on the agreement scale. However, the average responses from 110 students for each survey item ranged from 51% to 78%. The overall mean response for all the entire survey was 70% agreement.

The top three statements with the greatest agreement early in the semester were 19, 10, and 8, respectively. These statements had at least 76% agreement across the class and were based upon their peers' innovative, empathic, and project skills. It is important to note that although these students were in their teams for a limited period of time, they believed that their peers could consider the viewpoint of others and to explore new ideas. The least agreed upon statements were numbers 30, 31, and 7. These statements focused upon the empathy and social impact of engineers. Further, five of responses with the greatest agreement were statements in the innovative category, while the remaining were in knowledge, communication, creative, and empathy categories. Four of the statements with least agreement were social impact category, three more were based on tactile/visual traits of their peer, with the remaining being empathy, project skills, and communication.

Table 2. Average Agreement Response for Each Survey Item

Q#	Initial Mean	Q#	Initial Mean	Q#	Initial Mean
1	75%	14	74%	27	72%
2	75%	15	68%	28	66%
3	67%	16	73%	29	72%
4	75%	17	67%	**30**	**51%**
5	68%	18	72%	**31**	**61%**
6	75%	19	78%	32	66%
7	**63%**	20	75%	33	74%
8	76%	21	75%	34	71%
9	75%	22	70%	35	67%
10	76%	23	71%	36	69%
11	76%	24	74%	37	66%
12	71%	25	66%	38	67%
13	74%	26	72%	39	65%

These results show that the participants believed their peers pursued engineering for their interest in innovation instead of an interest in social impacts on society. This may have been reinforced by the undergraduate curriculum. Although students are required to have at least nine credit hours of social science courses, the curriculum mainly focuses on engineering courses that teach methods and tools to solve problems and may not directly relate them to current social issues. To ensure that students understand and are encouraged to pursue social responsibilities in the field of engineering, additional instruction could be supplied which provides examples of how engineers must apply their understanding of engineering principles to real world issues.

4.2 Change in Responses

The survey given early in the semester was repeated closer to the end of the semester when the teams had mostly finished their team project. Therefore, this repeated survey measured the perception of students regarding their team members after ten weeks of collaboration on the team project. Table 3 shows the mean response for each survey item and the change in mean response from the previous survey.

The individual agreement responses ranged from as low as 1% to a maximum of 93% on the agreement scale. However, the average responses from 123 students for each survey item ranged from 57.1% to 74.8%. The overall mean response for all the survey items was 70.1% agreement. As shown in Table 3, 23 of the 39 survey items resulted in lower agreement levels on average, whereas the remaining 16 items saw higher level of agreement on average when compared to the early semester surveys (shaded). Moreover, the maximum positive change in the agreement level can be seen on survey item 28 which deals with creativity and problem-solving capabilities. The largest negative change in the response can be seen on survey item 34 which deals with the social impact of engineering.

Table 3. Late Semester Mean Reponses and Change in Mean Responses

Q#	Final Mean	Delta	Q#	Final Mean	Delta	Q#	Final Mean	Delta
1	72%	-3%	14	74%	0%	27	73%	1%
2	72%	-3%	15	67%	0%	28	72%	6%
3	70%	3%	16	71%	-2%	29	73%	1%
4	71%	-4%	17	67%	0%	30	57%	6%
5	68%	-1%	18	71%	-1%	31	64%	3%
6	75%	-1%	19	74%	-4%	32	69%	2%
7	69%	6%	20	74%	-1%	33	72%	-3%
8	72%	-4%	21	74%	-1%	34	65%	-6%
9	73%	-2%	22	71%	1%	35	65%	-1%
10	73%	-3%	23	70%	-1%	36	69%	0%
11	72%	-3%	24	72%	-2%	37	67%	0%
12	71%	0%	25	67%	1%	38	68%	1%
13	70%	-4%	26	72%	1%	39	68%	4%

The changes shown in Table 3 are small changes, within 10% of the median responses. Therefore, in order to analyze the statistical significance of these changes, a two-sample t-test was conducted for each survey item assuming unequal variances. Table 4 shows the results of the t-tests. The test was set up with a hypothesized mean difference between the two samples being zero. Therefore, a rejection of the null hypothesis would show that the responses from the early semester survey and the late semester survey were significantly different. It should be noted that each of the t-tests presented only compare the responses in early and late semester. Therefore, a Bonferroni adjustment is not necessary as this set of tests does not encounter the problem of multiple comparisons.

Table 4. Two-Sample t-Test Results for Each Survey Item

Q#	p-value	Q#	p-value	Q#	p-value
1	0.079	14	0.926	27	0.611
2	0.075	15	0.864	28	0.008
3	0.152	16	0.302	29	0.745
4	0.003	17	0.874	30	0.034
5	0.805	18	0.785	31	0.150
6	0.742	19	0.040	32	0.264
7	0.010	20	0.709	33	0.120
8	0.029	21	0.593	34	0.011
9	0.269	22	0.710	35	0.594
10	0.109	23	0.643	36	0.980
11	0.041	24	0.291	37	0.858
12	0.796	25	0.525	38	0.614
13	0.049	26	0.799	39	0.123

As shown in Table 4, nine out of 39 survey items showed a significant difference using a significance level of 0.05 (shown in green). However, reviewing the p-values, survey items 1 and 2 are relatively close to the significance level. Significant changes were seen in survey items 4, 7, 8, 10, 13, 19, 28, 30, and 34. Four of these survey items were based on innovative skills while the remaining focused on communication, empathy, project skills, and social impact.

Of note is the significant change in the social impact statement 34 that asks if the participant's peers are "interested in improving engineering education for K-12 students", Most of the statements that had the greatest disagreement were based on social impacts. This significant change to decrease agreement with improving K-12 engineering education suggests that college courses that provide a social impact directly impacts social peer efficacy.

Statements 4, 7, 19, and 28 each focused on the innovative skills of the participant's peers. The skills of identifying new products, processes, and ideas were explored in statements 4 and 7. The mean increased over the course of the project, which signifies that as the participants continued working together, they began to think more highly of each other's innovative skills. Statements 19 and 28 focus primarily on persistence and repurposing to create new idea or solution. While students' peer efficacies decreased for their peers' persistence in solving problems, the largest increase in peer efficacy was for repurposing new uses for existing methods or tools. Although these seem somewhat contradictory, it shows that these participants believed their peers to be able to work through certain problems but students may not have been willing to invest the necessary effort.

Statements 8 (empathy), 30 (communication), and 10 and 13 (project skills) were the remaining statements with the greatest changes observed throughout the team project. Statement 8 is based on how well team members are able to consider the viewpoints of others. This saw the third largest decrease of all survey results, which reveals that as participants continued to work together through the project, they felt as though their viewpoints may not have been as well received as they could have been. It is generally accepted that more consideration of other viewpoints leads to better results as a team, but more research is required to determine the validity of that sentiment for this project. Statement 30 had the second largest increase through both surveys suggesting that the participants believe their peers enjoy reading about engineering. This can also lead to better innovation as a common attribute of innovators is that they maintain their understanding of current technology and engineering practices, although this could be affected by all the participants currently being students that are recommended to read textbooks.

Statements 10 and 13 focused on the project skills of the participants' peers. Results from both statements saw decreases regarding team members' abilities to apply lessons from similar situations to current problems and if team members are able to set clear goals. Peer efficacy from statement 13 may have specifically decreased due to the stresses from the end of the project where work on the project was nearing its final due date. This can create situations where changes are made to the final deliverable and each individual working on the project may end up having their own goals that are not well communicated.

4.3 Team Based Results

As the design project was a team based project where the team assignments remained the same throughout the semester, a team based analysis was done to investigate the change in team responses over the course of the semester. Table 5 shows the changes seen in the average response of the teams for each survey category. This average is calculated by combing responses for each statement in the category for all team members.

More than half of the teams evaluated showed a positive change in the knowledge, innovative, creative, tactile/visual, and communication categories. This result is expected as the knowledge and skills evaluated by these categories are part of the course material and students are expected to improve on these throughout the course. Alternatively, more than half of the teams showed a negative change in responses for empathy, project skills, and social impact categories. Decreases for empathy and social impact are expected as the metrics evaluated by these categories are generally not the focus of the course. However, the result seen for project skills are not expected and deserve a more in-depth analysis.

5 CONCLUSION AND FUTURE WORK

The results of this study reveal that engineering students' perceptions of their peers' efficacy regarding their engineering knowledge, ability to communicate, and product developments skill increased over the course of the semester long design project. Additionally, the students' views of their peers' efficacy pertaining to social impact, customer empathy, and project skills decreased. These conclusions are beneficial as they show how the effect of the students' education at Clemson University adjusts the students' peer efficacy. Educators can apply some of the techniques used by Clemson University and presented in this paper to potentially observe a change in their students' peer efficacy. Although the term project was to develop devices for local elementary schools, the students appear to be more focused on the engineering problem itself rather than the social impact of engineering. These conclusions require additional analysis in order to determine their causes.

The relationship between these findings and student grades will be investigated in the future to determine if the students' evaluations of their peers compares well to the instructor evaluations. This study could be repeated with capstone design students instead of pre-capstone. The results from the pre-capstone study could be compared to the future capstone study in order to analyze how each class changes students' perceptions of their peers. Finally, the elementary school students' perceptions could be studied to gauge an understanding of the impact the service project has on their views of engineering.

Table 5. Change in Team Responses Based on Categories

Team	Empathy	Knowledge	Innovative	Creative	Project Skills	Tactile / Visual	Commun-ication	Social Impact
1	1.0%	4.9%	-1.3%	-6.4%	2.5%	-0.7%	4.8%	-10.0%
2	-20.6%	-18.3%	-7.0%	-4.3%	-7.4%	1.3%	-1.3%	0.1%
3	-1.2%	-3.3%	2.6%	2.2%	3.2%	0.2%	0.4%	0.3%
4	-13.5%	-0.4%	-4.7%	-8.8%	-6.8%	-5.8%	-8.5%	-3.5%
5	-4.3%	1.1%	3.6%	3.8%	1.4%	2.5%	5.5%	3.7%
6	0.5%	2.1%	1.2%	6.0%	-2.9%	-1.4%	0.8%	-1.6%
7	-6.1%	-2.2%	0.0%	0.7%	-1.8%	1.8%	-4.9%	-0.2%
8	-4.8%	1.7%	-3.7%	-5.8%	-3.8%	2.2%	1.5%	-6.1%
9	3.4%	1.0%	-0.8%	1.0%	-2.8%	-2.5%	-6.2%	-0.5%
10	-0.7%	0.1%	-6.1%	3.1%	-13.3%	1.2%	-6.2%	-10.5%
11	-18.9%	-15.0%	-9.7%	-9.1%	-14.1%	-12.8%	-6.3%	-15.7%
12	7.5%	19.8%	10.0%	5.5%	5.7%	2.2%	1.1%	3.8%
13	-3.0%	-6.2%	0.9%	0.1%	-0.6%	4.8%	2.5%	6.2%
14	5.1%	2.6%	4.4%	1.8%	2.1%	4.1%	7.4%	-3.9%
15	0.9%	4.2%	1.8%	1.9%	-3.1%	5.7%	-1.0%	4.6%
16	6.8%	4.9%	7.6%	2.6%	3.5%	4.2%	7.9%	6.6%
17	-10.3%	-8.4%	-7.1%	-6.3%	-8.6%	-7.3%	-9.9%	-8.1%
18	-3.1%	6.5%	2.0%	2.2%	-3.9%	9.4%	13.0%	7.5%
19	-0.2%	2.9%	7.0%	7.3%	3.0%	7.9%	10.8%	13.9%
20	-15.8%	-6.3%	-15.1%	-18.1%	-13.8%	-7.0%	-14.4%	-8.9%

REFERENCES

Born, W. & Schmidt, L. (2016), An Observational Study on Functional Behavior in Team Design. *IDETC/CIE*, pp.1–10.

Carberry, A.R., Lee, H.-S. & Ohland, M.W. (2010), Measuring Engineering Design Self-Efficacy. *Journal of Engineering Education*, 99, pp.71–79.

Derue, D.S. et al. (2011), Trait and Behavioral Theories of Leadership : an Integration and Meta-Analytic Test of Their Relative Validity. , pp.7–52.

Ertas, A. & Jones, J.C. (1993), *The Engineering Design Process* 1st ed., New: John Wiley & Sone. Inc.

Hanus, J. & Russell, J.S. (2007), Integrating The Development Of Teamwork, Diversity, Leadership, And Communication Skills Into A Capstone Design Course. In *ASEE Annual Conference and Exposition*.

Hutchison, M.A. et al. (2006), Factors Influencing the Self-Efficacy Beliefs of First-Year Engineering Students. *Journal of Engineering Education*, 95(1), pp.39–47.

Hyman, B.I. (2001), From capstone to cornerstone: A new paradigm for design education. *International Journal of Engineering Education*, 17(4/5), pp.416–420.

Ibn-E-Hassan et al. (2014), Influence of national and engineering culture on team role selection. *International Journal of Technology and Design Education*, 24(1), pp.91–105.

Joshi, S., Morkos, B. & Summers, J.D. (2011), Mapping Problem and Requirements To Final Solution : a Document Analysis. In *Proceedings of the ASME IDETC/CIE 2011*. Washington, DC, pp. 1–10.

Joshi, S. & Summers, J.D. (2015), Requirements Evolution: Understanding the Type of Changes in Requirement Documents of Novice Designers. In *ICoRD'15–Research into Design Across Boundaries Volume 2*. Bangalore, India: Springer, pp. 471–481.

Kratzer, J., Leenders, R.T.A.J. & Van Engelen, J.M.L. (2008), The social structure of leadership and creativity in engineering design teams: An empirical analysis. *Journal of Engineering and Technology Management - JET-M*, 25(4), pp.269–286.

Kress, G. & Schar, M. (2011), Initial Conditions: The Structure and Composition of Effective Design Teams. In *International Conference on Engineering Design, ICED'11*. Copenhagen.

Kumar, S. & Hsiao, J.K. (2007), Engineers Learn "Soft Skills the Hard Way": Planting a Seed of Leadership in Engineering Classes. *Leadership Management in Engineering*, 7(1), pp.18–23.

Lent, R.W. et al. (2008), Longitudinal relations of self-efficacy to outcome expectations, interests, and major choice goals in engineering students. *Journal of Vocational Behavior*, 73(2), pp.328–335.
Lent, R.W., Brown, S.D. & Larkin, K.C. (1984), Relation of self-efficacy expectations to academic achievement and persistence. *Journal of Counseling Psychology*, 31(3), pp.356–362.
Lent, R.W., Brown, S.D. & Larkin, K.C. (1986), Self-efficacy in the prediction of academic performance and perceived career options. *Journal of Counseling Psychology*, 33(3), pp.265–269.
Maier, J.R.A. et al. (2010), Case Study Research Using Senior Design Projects: An Example Application. *Journal of Mechanical Design*, 132(11), p.111011.
Marin, J. a, Armstrong, J.E. & Kays, J.L. (1999), Elements of an Optimal Capstone Design Experience. *Journal of Engineering Education*, 88(January), pp.19–22.
Morgeson, F.P., DeRue, D.S. & Karam, E.P. (2010), *Leadership in Teams: A Functional Approach to Understanding Leadership Structures and Processes*.
Ohland, M.W. & Summers, J.D. (2007), Teaching Design Using Multiple Hierarchical Engineering Education Models. *International Journal of Engineering Education*, 22(3), p.577.
Ostergaard, K.J. et al. (2007), An experimental methodology for investigating communication in collaborative design review meetings. *International Journal of CoCreation in Design and the Arts*, 1(December 2012), pp.37–41.
Ostergaard, K.J. & Summers, J.D. (2003), A taxonomic classification of collaborative design. In *Proceedings of the 14th International Conference on Engineering Design ICED03*. pp. 617–618.
Pahl, G. et al. (2007), *Engineering Design: A Systematic Approach* 3rd ed., London: Springer-Verlag London Limited.
Pahl, G. & Beitz, W. (2013), *Engineering Design: A Systematic Approach*, Springer Science & Business Media.
Palmer, G. & Summers, J.D. (2011), Characterization of Leadership Within Undergraduate Engineering Design Teams Through Case Study Analysis. *International Conference on Engineering Design 2011, Copenhagen, Denmark*, p.204.
Patel, A. et al. (2016), Function Modeling: A Study of Sequential Model Completion Based on Count and Chaining of Functions. In *ASME International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*. Charlotte, NC, USA: ASME, p. DETC2016-59860
Powers, L.M. & Summers, J.D. (2009), Integrating graduate design coaches in undergraduate design project teams. *International Journal of Mechanical Engineering Education*, 37(1), pp.3–20.
Seat, E., Parsons, J. & Poppen, W. (2001), Enabling Engineering Performance Skills: A Program to Teach Communication, Leadership, and Teamwork*. *Journal of Engineering …*, (January), pp.7–12.
Summers, J.D., Joshi, S. & Morkos, B. (2014), Requirements evolution: Relating functional and non-functional requirement change on student project success. In *ASME 2014 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*. Buffalo, NY: American Society of Mechanical Engineers, p. DETC2014-35023
Thimmaiah, S., Phelan, K. & Summers, J.D. (2017), An Experimental Study on the Influence That Failure Number, Specialization, and Controls Have on Confidence in Predicting System Failures. *Journal of Mechanical Design*, 139(1), p.11102.
Todd, R.H., Sorensen, C.D. & Magleby, S.P. (1993), Designing a Senior Capstone Course to Satisfy Industrial Customers. *Journal of Engineering Education*, 82(2), pp.92–100.
Ullman, D.G. (2010), *The Mechanical Design Process* 4th ed., New York, NY: McGraw-Hill.
Wewers, M.E. & Lowe, N.K. (1990), A critical review of visual analogue scales in the measurement of clinical phenomena. *Research in Nursing & Health*, 13(4), pp.227–236.
Zapata-ramos, M.L. & Perez-vargas, M.J. (2016), Promotion of Innovation and Entrepreneurship in Engineering Design by Synchronizing Engineering and Business School Courses. In *ASME International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*. Charlotte, NC: ASME, p. DETC2016-59701. Available at: http://proceedings.asmedigitalcollection.asme.org/proceeding.aspx?articleid=2591746