Gender-Based Comparison of Creative Self-Efficacy, Mindset, and Perceptions of Undergraduate Engineering Students

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Dr. Delahanty is a Program Director at NSF in the Division of Undergraduate Education (EDU/DUE), and has a background in physics, electrical engineering, and STEM Education, with a concentration in creativity and innovation. Her research focuses on creative self-efficacy, creative mindset, and perceptions of engineering majors, particularly women, to offer insight into why there are so few women in the major and in the profession. She was an NSF ATE Mentor Connect Mentor Fellow in 2022. She is an Emeritus Professor of Engineering and Physics at Bucks County Community College where she was the Principal Investigator of two NSF Advanced Technological Education (ATE) grants, focusing on workforce readiness, and creating pathways from non-credit into credit programs. She also taught at The College of New Jersey (TCNJ) in the School of Engineering for 15 years. With funding from these ATE grants she created two technician education programs, and enhanced the engineering major at her community college. Dr. Delahanty established technical, college level, programs of study for modernized classroom and laboratory including six online course platforms that meet Quality Matters (QM) standards. She was the faculty advisor to student research teams, where two teams made the final round of the AACC Community College Innovation Challenge (CCIC) in 2016 and 2017. Dr. Delahanty has developed and conducted STEM focused outreach initiatives to community groups and in K-12 schools with a higher percentage of underrepresented and underserved students. Prior to her teaching career, Dr. Delahanty was an electrical engineer at General Electric Company in both military and commercial satellite communications.

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Abstract

This study builds on prior research, and compares the creative self-efficacy, creative mindset, and perspectives of engineering as creative of female and male undergraduate engineering majors. The intention is to help to provide insight into why only approximately 20% of engineering graduates are women, 15% of female engineering graduates never enter the profession, and the engineering field is comprised of only 16.5% women. To better understand why women choose engineering, their perspectives on creativity, and how they connect to success in engineering, a mixed methods study was conducted to analyze how creative self-efficacy (CSE), creative mindset, and lived experiences lead women undergraduate students to choose engineering. The initial study was comprised of a survey of CSE, and creative mindset distributed to undergraduate women engineering majors, and interviews of selected volunteers who completed the survey. The synthesis of findings from the initial study revealed that CSE and creative mindset were related to lived experiences. This research, which extended the initial study to include male participants, sought to help to answer the research question, "How do creative self-efficacy, creative mindset, and perceptions of engineering as a creative field compare between female and male undergraduate engineering students?" The survey was distributed nationally to engineering majors and engineers in the field. Analysis of a subset of survey responses from undergraduate engineering majors that included 197 women and 211 men revealed that (1) for all students, as both GPA and CSE increased, Growth Creative Mindset (GCM) or the belief that creativity can be cultivated increased. (2) women were less likely than the men to have a Fixed Creative Mindset (FCM), or the belief that creativity cannot be improved, (3) CSE had no effect on FCM for women, but for men, as CSE increased the belief that creativity cannot be improved also increased, (4) for women, progression in the engineering major, and for both groups, succeeding to the senior year contributed to the increased belief that engineering is a creative field.

Introduction

Creativity within engineering is integral to the profession and diversity is crucial to innovation in engineering design [1]-[3]. However, there is a common perception that engineering, and creativity are not connected, Cooper and Heaverlo [1] reported that “only three percent of adults in the U.S. perceive engineering as being creative” (p. 29). The creative aspect of engineering was linked to female interest in the field, where women engineers are known to enjoy creativity applied to problem solving in engineering [2], [4]. Despite the need for the diverse perspectives of women engineers, in 2020 women comprised 24% of all engineering graduates, and this percentage has increased very slowly in the 20 year time span [1], [6], [7]. In addition, this increase in percentage from previous years has been attributed to lower percentages of men attending college as opposed to an increase in women students entering the major [5]. In 2023, 16.5% of all engineers in the field were women, and 15% of women graduates never entered the profession [8]. Another notable statistic is that 40% of women graduates that enter engineering jobs are known to leave the field within 10 years [8].

To better understand perspectives, mindset, and beliefs on creativity in relation to women and engineering, a mixed methods study was conducted that focused on how creative self-efficacy (CSE), creative mindset, and lived experiences lead undergraduate female students to choose engineering as a major and succeed [8]-[13]. This research is an extension of the initial study and includes male undergraduate engineering students. CSE and growth creative mindset (GCM) have been reported on in research on gender comparisons, and this study offers insight on fixed creative mindset (FCM) in addition to CSE and GCM.

Literature

There are many factors that influence female students and their choice of engineering as a major. These factors include social and educational influences that affect mindset, self-efficacy, CSE, and engineering identity. A greater exposure to creativity in engineering education increases intrinsic motivation leading to a growth mindset and greater self-efficacy, but the literature revealed that there are gender differences in the driving force behind this motivation.

Self-Efficacy and Social Influences. Self-efficacy is defined as one's own belief in their ability to perform a particular task or to succeed in a particular domain [10]. Self-efficacy is known to develop through repeated successes, where the negative impact of failures is diminished by these successes [18], [28] - [30]. Studies comparing the self-efficacy of females and males found that, females are more likely to derive self-efficacy from verbal reinforcement, strong social networks, mentors, and other positive social influences, whereas males have been shown to derive self-efficacy through the mastery of a task [14]. Research that focused on self-efficacy of female and male students revealed that female students had higher self-efficacy than males in areas where there was support and mentorship [10], [18]. Social influences that include beliefs, social networks, personal relationships, environment, and classroom atmosphere were highlighted as contributing factors to the self-efficacy and mindset of female students, and to their persistence in STEM and engineering [13] - [18]. The importance of personal influences such as teachers, family, and friends have a greater impact in encouraging female students are twice as likely than their male counterparts to seek engineering, when influenced by someone in their lives [16].

Women perceive engineering as a career path where they will receive little support due to the lack of women [17], [22], [23]. Women role models are particularly important in male dominated fields such as engineering because they offer a less threatening environment [4], [17], [19]. In 2021, only 19.5% of tenured or tenure track faculty in engineering were women [20], [21]. Women engineering majors rely on strong social networks for coping, and these networks have been shown to be more important than grades [4], [23]. Persistence as opposed to performance was determined to be a factor related to the retention of women engineering students [23].

Educational Challenges Facing Female Students. Female students face unique challenges within both pre-college and college education that deter them from entering or completing the engineering major [17], [19]. Negative stereotypes that are still prevalent at all levels of education are known to affect the aspirations and performance of girls in math and science, and their ultimate choice of major and profession [19]. Two major stereotypes that still exist as early as elementary school are (1) that boys are better at math than girls, and (2) that science is more suited to boys. These stereotypes lead to negative perceptions that professions requiring high level mathematical skills, and certain science fields are just for men [19]. Female students face other challenges of stereotyping in addition to gender bias in education, where, although they score higher in math and science, male students are described as getting more attention in class and were considered to be better at math and science than the female students. This resulted in lower self-efficacy of the female students than their male peers [13], [17]. The lack of self-efficacy of female students in math and science was connected to a lack of encouragement, which in turn lead to disinterest in the subject matter and prevented female students from pursuing these subjects as a major [17].

Creativity and Diversity in Engineering. Diversity is important as a link to the success of the creative component of engineering, and the creative aspect that offered a female perspective, is crucial to innovation in the profession [2], [3]. The creative aspect of engineering, which is known to be appealing to women, has been studied as a factor in the retention of women in the engineering major and in the profession [16], [24] - [27]. Welcoming different perspectives in a atmosphere that cultivates diversity is necessary for innovation. It is crucial to combine the creative talents of women and men in engineering to most efficiently and effectively produce the useful outcome or product, and to devise creative solutions to existing problems [2], [16], [27].

Creativity in Engineering Education. Employers reported that graduates were entering the workforce with limited skills necessary for problem solving and creativity, and were not adequately equipped to handle complex engineering problems [3], [24], [31]. The need for creativity in engineering-centered design activities was highlighted as a crucial aspect of curricula, in all educational settings [3], [4], [25] - [27], [32]. Engineering graduates are often not properly prepared for engineering design, which is a critical component for innovation in the industry [33]. Traditional engineering programs do not adequately prepare students to be design engineers. Despite advances in engineering education, there is a substantial disconnect between engineering education and the practice of engineering, that includes teamwork, collaboration, business and marketing skills in addition to traditional engineering skills [31], [33]. In the ABET Criteria for Accrediting Engineering Programs, to prepare engineering students for industry, creativity was highlighted in the engineering curriculum, as a necessary element for accreditation, where ABET defined engineering design as an iterative process leading to a product or solution of the highest possible quality [34].

Project-based learning (PBL) in education is comprised of open-ended projects that fulfill a real-world need or societal problem. PBL employs engineering practice comprised of teamwork, collaboration, problem resolution and the engineering design process (EDP) to arrive at a solution or produce a product [26]. Positive learning outcomes of open-ended, engineering-centered problems utilizing the EDP included ownership, creativity, confidence, acceptance of failure, and motivation to complete a goal [2], [3], [35]. Design thinking and creativity, integral components of the EDP, and keystones of engineering-centered problems are crucial to preparing students for the diverse perspectives needed in the engineering profession [2], [24], [26], [34], [35]. Research revealed that at all educational levels, adequate preparation involving design thinking and creativity was lacking, and this issue needed to be addressed in order to accommodate the need for diversity in the industry [2], [24], [27].

Creative Self-Efficacy (CSE), Intrinsic Motivation, and Creative Personal Identity (CPI). CSE is defined as one's own belief in their creative abilities to produce a creative result [28], [8], [9], [15], [23], [24]. The development of CSE is an iterative process that is developed over time, and with repeated creative successes [28], [29]. Tierney and Farmer [28] distinguished between confidence and self-esteem, and creative self-efficacy, where self-esteem was associated with more generalized feelings, and creative self-efficacy was connected to more specific interests. CSE is defined as creativity specific, whereas general self-efficacy spans domains, and general self-efficacy is related to CSE [28], [36]. CSE has been studied as a part of student success in engineering education, and with respect to the retention of women engineering students in the major [8], [9], [24], [32]-[35], [37], [38]. CSE has been related to creative performance, where perseverance in the face of barriers or challenges, is a necessary component of success in completing creative work [28]. Succeeding at more complex tasks, such as open ended engineering problems, was shown to diminish the effects of threatening situations, increase acceptance of failure, increase intrinsic motivation or internal drive to continue, and become ingrained in long-term memory [39], [40], [41]. Although complex tasks have been associated with lowering self-efficacy, CSE was shown to have the opposite effect. "…beliefs that tasks are complex may depress self-efficacy levels" differed when applied to creative self-efficacy where complexity of the task increased intrinsic motivation ([28], p. 1140).

CSE has been studied in relation to gender and creative personal identity (CPI), or perceived creativity of self. As self-efficacy increases, efficiency in fulfilling a task increases, which is connected to greater control of a situation and a greater likelihood of success. [11]. CPI, or self-description of the importance of creativity, is cultivated through environment that includes social interactions and opportunities to engage in creative activities [11]. CSE and CPI were significantly, positively correlated, and were seen to contribute to intrinsic motivation, divergent thinking, and "self-reported originality" ([11], p. 216), [28]. Gender differences were seen between males and females in both CPI and in CSE where females are influenced more by social factors than by goal fulfillment or achievements [11], [14], [18].

Growth and Fixed Creative Mindset (GCM and FCM). Mindset has been studied with respect to intellectual and creative growth and achievement [12], [42]. A fixed mindset or the belief that intellect or creativity cannot be cultivated or changed is known to inhibit the growth of individuals in this domain. Conversely, growth mindset is the belief that intellect or creativity can improve with practice and perseverance and has been connected to a greater likelihood of goal completion. Dweck [12] reported that a poll of researchers studying creativity and mindset agreed that the most important factor related to creative achievement was perseverance, a direct product of growth mindset. Those with a growth mindset are known not to be as affected by the outcomes of learning, but are more highly invested in the learning itself [12], [42]. In studies, those with a fixed mindset were only interested in knowing their score and if answers were right or wrong, not why they had gotten a wrong answer, or what the correct answer was [12].

Intrinsic motivation is a factor in the cultivation of a growth mindset and connected to an increase in CSE [8], [9]. Female students who have strong social influences show an increase in intrinsic motivation and perseverance that is characteristic of a growth mindset, and has been shown to increase their identification with the engineering major leading to retention in the major [8], [15], [24]. Studies have differed in findings related to comparisons of growth creative mindset (GCM) of females and males, where there have been reports of no differences, and also reports of females having a higher GCM than males [36], [42]. Analysis of CSE in comparison to both GCM and fixed creative mindset (FCM) of women and men undergraduate engineering majors is a focus of this study.

Research Question

The intention of this study was to help to answer the research question: "How do CSE, creative mindset, and perceptions of engineering as a creative field compare between female and male undergraduate engineering students?" This question was framed to better understand differences and similarities in CSE, mindset, and perceptions of women and men undergraduate engineering students. It is expected that this research will offer insight into how creativity and mindset affect women and men students differently in their pursuit of an engineering degree.

Methodology and Instrument

The instrument used in this study was comprised of the CSE assessment, and a measurement of beliefs about creativity or creative mindset that was utilized in the research by Delahanty and Silverman [8], [9], [28], [29]. Answer choices to the three question CSE assessment, and the creative mindset measurement, were in the form of a five-point Likert scale: "Strongly Agree" to "Strongly Disagree." The survey responses were separated into three categories for analysis [8], [9]. There were three questions to assess CSE from a validated questionnaire developed by Tierney and Farmer [28]. There were 10 questions from a survey that assessed GCM and 5 questions that assessed FCM [8], [9]. Scores from groups of questions relating to CSE, GCM, and FCM were analyzed quantitatively and totaled for each parameter for the subset of data comprised of undergraduate engineering majors.

Examples of survey statements related to CSE, GCM, and FCM [8], [9], [28], [29]:

1. CSE: "I have confidence in my ability to solve problems creatively"
2. GCM: "Being creative will help me excel in my engineering career"
3. FCM: "You are either creative or not. Even trying very hard you cannot change much."

Quantitative analysis of this data was intended to help to answer the research question.

Population

The survey was distributed nationally through the Society of Women Engineers (SWE) and extended to other engineering professional societies and universities, to engineering students of all genders and levels and to engineers in the field who volunteered to complete the survey. There were 704 valid responses to the survey. A subset of responses comprised of declared undergraduate engineering majors was analyzed in this portion of the study. There were 411 respondents who completed all questions on CSE, GCM, and FCM (48% (N= 197) declared female and 51.5% (N= 211) declared male) out of 443 submissions from respondents who indicated in the demographics section that they were undergraduate engineering students. Because scores for CSE, GCM, and FCM were summed based on respective survey questions, it was necessary to vet the survey based on completion of all questions related to these parameters. A very small proportion of participants identified as Other and Prefer Not to Say or did not answer the question on gender; the sample size was not large enough to analyze these two groups, and they should be considered in future studies.

Findings from Survey Comparisons and Discussion

Demographic Information. Demographic information for survey respondents including age, year in college, engineering concentration, and GPA is depicted in Table 1. Students listed as seniors included declared undergraduates that were in their programs for more than 4 years.

Table 1. *Frequency Tables for Age, Year in College, Engineering Concentration, and GPA Range*

Women	Age	Frequency	Percent
Valid	18-24	176	89.3
	25-34	11	5.6
	35-44	6	3.0
	45-54	4	2.0
	Total	197	100.0

Men	Age	Frequency	Percent
Valid	18-24	173	82.0
	25-34	29	13.7
	35-44	8	3.8
	45-54	1	.5
	Total	211	100.0

	Year in College	Frequency	Percent
Women Valid	First Year	49	24.9
	Second Year	67	34.0
	Junior	55	27.9
	Senior*	21	10.6
	Total	192	97.5
Missing	System	5	2.5
Total		197	100.0

	Year in College	Frequency	Percent
Men Valid	First Year	68	32.2
	Second Year	67	31.8
	Junior	62	29.4
	Senior*	13	6.2
	Total	210	99.5
Missing	System	1	.5
Total		211	100.0

	Women	Frequency	Percent
Valid	Other (specify)	4	2.0
	Architectural	22	11.2
	Biological	21	10.7
	Biomedical	22	11.2
	Civil Environ.	15	7.6
	Civil Structural	31	15.7
	Electrical	15	7.6
	Mechanical	23	11.7
	Chemical	10	5.1
	Computer	20	10.2
	Industrial	13	6.6
	N/A	1	.5
	Total	197	100.0

	Men	Frequency	Percent
Valid	Architectural	38	18.0
	Biological	17	8.1
	Biomedical	21	10.0
	Civil Environ.	16	7.6
	Civil Structural	23	10.9
	Electrical	16	7.6
	Mechanical	19	9.0
	Chemical	22	10.4
	Computer	15	7.1
	Industrial	24	11.4
	Total	211	100.0

	GPA	Frequency	Percent
Women Valid	0.0 - 1.9	1	.5
	2.0 - 2.49	38	19.3
	2.5 - 2.99	40	20.3
	3.0 - 3.49	59	29.9
	3.5 - 3.99	57	28.9
	4.0	1	.5
	Total	196	99.5
Missing	System	1	.5
Total		197	100.0

	GPA	Frequency	Percent
Men Valid	0.0 - 1.9	3	1.4
	2.0 - 2.49	48	22.7
	2.5 - 2.99	60	28.4
	3.0 - 3.49	47	22.3
	3.5 - 3.99	53	25.1
	Total	211	100.0

*Includes co-op students, students in 5-year programs, etc.

Consistent with the average age of the undergraduate college student population [43], 86% (n=249) of all survey respondents were between the ages of 18 – 24; 89.3% (n=176) of women and 82% (n=173) of men were in this age range. The engineering concentrations that had the largest percentage of women students were civil structural (n=31, 15.7%), mechanical (n=23, 11.7%), architectural (n=22, 11.2%), and biomedical (n=22, 11.2%). The engineering concentrations that had the largest number of male students were architectural (n=38, 18%), industrial (n=24, 11.4%), civil structural (n=23, 10.9%), and chemical (n=22, 10.4%). The highest percentage of undergraduate students who completed the survey were in the first two years of college (n=116, 58.9% women and n=135, 64% men). The smallest percentages were from designated senior students. A greater percentage of women reported a higher GPA range than men; 59.3% (n=117) of women reported a GPA range of between 3.0 - 4.0, and 47.4% (n=100) of men reported a GPA of between 3.0 - 4.0.

Table 2. *Comparisons of Mean GPA range, CSE, GCM, and FCM for Women and Men Undergraduate Engineering Majors*

Means and Standard Deviations of GPA, CSE, GCM and FCM Based on Gender

	Gender	N	Min	Max	Mean Range	Std. Deviation
GPA Range Chosen	Female	196	1	6	3.6939⁺	1.11776
	Male	211	1	5	3.4692⁺	1.13923
CSE	Female	197	6	15	10.7360	2.17156
	Male	211	3	12	10.6493	2.00956
GCM	Female	197	25	50	36.4518	4.61076
	Male	211	27	50	36.1185	4.49764
FCM	Female	197	10	25	17.1066	3.11903
	Male	211	11	25	18.0332	2.76092

⁺Mean of the GPA range chosen in the survey, i.e.. Choice 3 is 2.5 – 2.99 (See Table 1).

Gender Comparisons of Means and Standard Deviations for GPA range, CSE, GCM, and FCM. Table 2 lists the means and standard deviations for GPA range, CSE, GCM, and FCM of N=197 women and N=211 men. There were five GPA ranges listed, with survey choices of 1 – 5 for the lowest GPA range to the highest GPA range, as is shown in Table 1. The mean score was computed from the survey choices 1 – 5, and the mean fell between the 2.5 – 2.99 range, choice 3 for both men and women, with the greater number of women choosing higher GPA ranges, thus the higher mean. Mean scores for CSE, GCM, and FCM were computed from survey choices where the value labels were as follows: Strongly Disagree (1), Disagree (2), Neither Agree nor Disagree (3), Agree (4), Strongly Agree (5). Thus, the higher scores in Table 3 for CSE, GCM, and FCM reflect the strength of agreement with the question.

Tests of Relationships: F-test, t-test, and Correlations. Levine's test for inequality of variances (F-test) and independent t-tests (95% confidence interval) were performed for GPA range, CSE, GCM, and FCMs. Findings are depicted in Table 3 and summarized in Table 5. Findings from the F-test revealed that there were no significant differences in variance, thus equal variances were assumed for the independent t-test. Findings from the independent t-test revealed that there were significant differences in GPA range chosen and FCM, between the female and male respondents. However, there was no difference in CSE or GCM.

Table 3. *F-test and Independent t-test for mean GPA Range, CSE, GCM, and FCM*

	F	Sig.	t	d.f.	1-Sided p	2-Sided p	Mean Diff.	Std. Error Diff.	95% Lower	95% Upper
GPA	.497	.481	2.006	405	.023	.046	.22468	.11200	.00452	.44485
CSE	.895	.345	-.419	406	.338	.675	-.0868	.2070	-.4937	.3202
GCM	.367	.545	.739	406	.230	.460	.33329	.45104	-.55337	1.21996
FCM	4.054	.045^{+}	-3.169^{+}	391.909^{+}	<.001	.002	-.92658	.29242	-1.50148	-.35167

$^{+}$Equal Variances Not Assumed

Table 4. *Correlations Based on Gender of mean GPA Range, CSE, GCM, FCM*

Female Students, N = 197		GPA	CSE	GCM	FCM
GPA	Pearson Correlation	1	.075	-.031	-.157*
	Sig. (2-tailed)		.296	.668	.028
CSE	Pearson Correlation	075	1	.252**	-.054
	Sig. (2-tailed)	.296		<.001	.453
GCM	Pearson Correlation	-.031	.252**	1	.040
	Sig. (2-tailed)	.668	<.001		.581
FCM	Pearson Correlation	-157*	-.054	.040	1
	Sig. (2-tailed)	.028	.453	.581	

Male Students, N = 211		GPA	CSE	GCM	FCM
GPA	Pearson Correlation	1	-.078	-.131	-.149*
	Sig. (2-tailed)		.262	.058	.031
CSE	Pearson Correlation	.078	1	.289**	.219**
	Sig. (2-tailed)	.262		<.001	.001
GCM	Pearson Correlation	.131	.289**	1	.299**
	Sig. (2-tailed)	.058	<.001		<.001
FCM	Pearson Correlation	-.149*	.221**	.299**	1
	Sig. (2-tailed)	.031	.001	<.001	

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

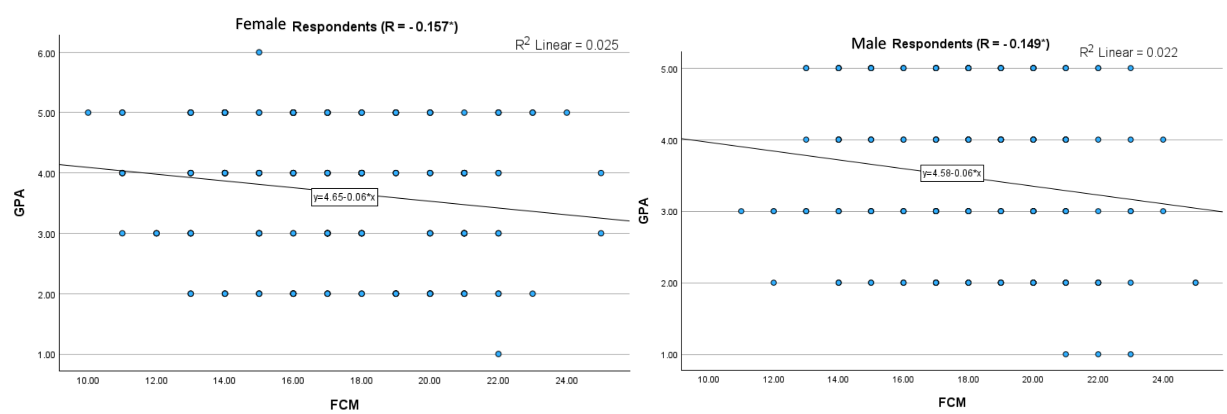
Correlations for age, GPA range, CSE, GCM, and FCM listed in Table 4, depicted graphically in Figures 1, 2, and 3, and summarized in Table 5, revealed several key findings highlighted by the shaded area in the tables):

1. no correlation: GPA range and CSE for both women and men
2. negative correlation: GPA range and FCM (0.05 level) for both women and men
3. positive correlation: CSE and GCM (0.01 level) for both women and men

4. no correlation: CSE and FCM for women
5. positive correlation: CSE and FCM for men (0.01 level)
6. no correlation: GCM and FCM for women
7. positive correlation: GCM and FCM for men (0.01 level)

Table 5. *Summary of Findings: Gender Comparisons of GPA Range, CSE, GCM, and FCM*

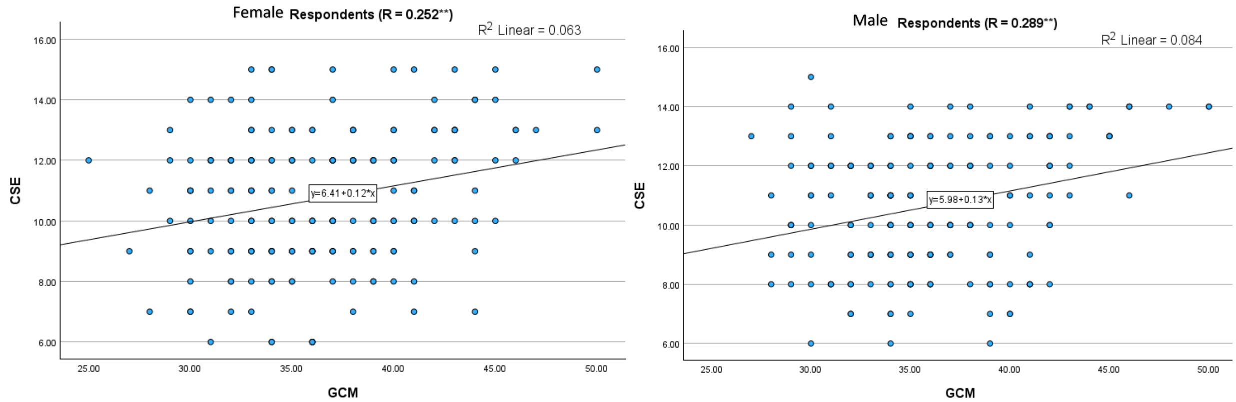
Summary of Findings: GPA Range, Creative Self-Efficacy (CSE), Growth Creative Mindset (GCM), and Fixed Creative Mindset (FCM) Comparisons*								
Gender	Independent Samples t-Test (Table 3)				Correlations (Table 4)			
	GPA Range	CSE	GCM	FCM	GPA-FCM	CSE-GCM	CSE-FCM	GCM-FCM
Female N = 197	Women: Significantly Higher (0.05 Level)	No Statistical Difference	No Statistical Difference	Women: Significantly Lower (0.01 Level)	Negative (0.05 Level)	Positive (0.01 Level)	No Correlation	No Correlation
Male N = 211							Positive (0.01 Level)	Positive (0.01 Level)
*Shading reflects differences in women and men respondents.								



*Significant negative correlation at the .05 level for both women and men. (See Table 4.)

Figure 1. Scatter plots of FCM vs. GPA Range for female and male survey respondents.

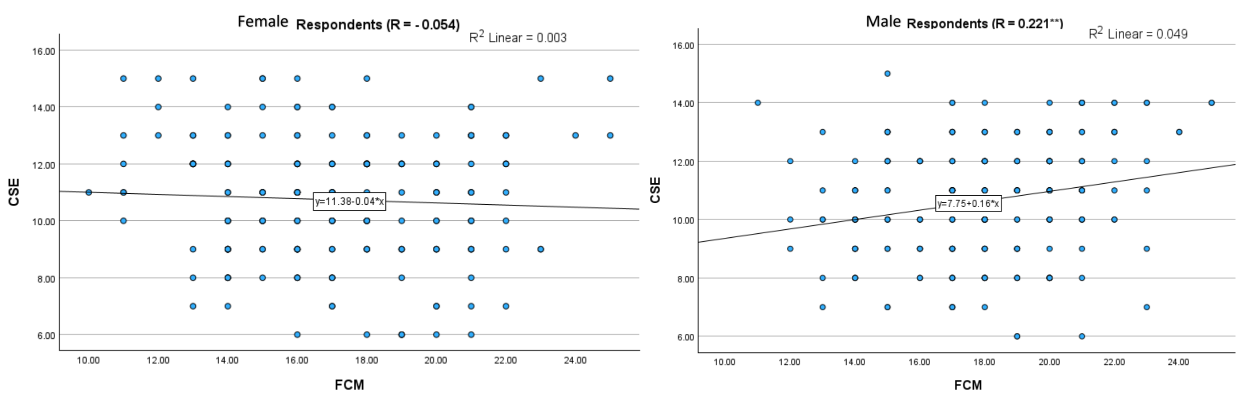
The findings from Table 4 and Figure 1 depict a significant negative correlation at the 0.05 level between GPA range and FCM for both women and men. The correlation coefficient was -0.157 (Sig. =0.028) for the women and -0.149 (Sig.= 0.031) or the men. This significant negative correlation suggested that as GPA increases, FCM decreases, or that a greater level of success in the major as was defined by higher GPA reduced the belief that creativity cannot be cultivated or improved for both women and men.



**Significant correlation at the .01 level for both female and male respondents. (See Table 4.)

Figure 2. Scatter plots of GCM vs CSE for female and male survey respondents.

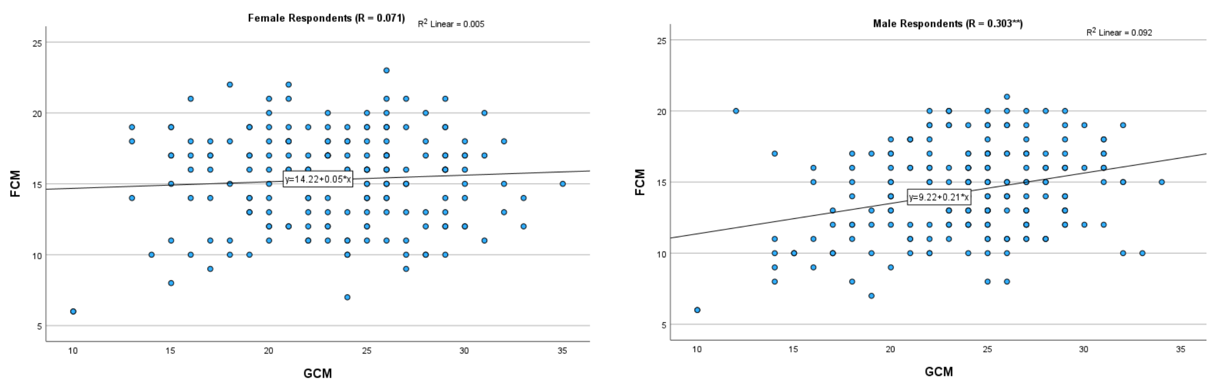
The findings in Table 4 and Figure 2 revealed statistical similarities between the women and men students with respect to CSE and GCM. As CSE increased GCM increased for both groups suggesting that an increase in CSE increased the belief that creativity can be cultivated or improved similarly for women and men.



**Significant correlation at the .01 level for male respondents. (See Table 4.)

Figure 3. Scatter plots of FCM vs CSE for female and male survey respondents.

Table 4 and Figure 3 revealed that there was no correlation between FCM and CSE for women, but there was a positive correlation between FCM and CSE for men. This suggested that for men as CSE increased, mindset that creativity cannot cultivated or changed increased. Table 4 and Figure 4 showed that there was no correlation for women between GCM and FCM, but for the men, there was a positive correlation between GCM and FCM. These findings suggested that additional research and analysis would be needed to better understand this finding. This would include interviews with survey respondents who indicated an interest to be interviewed, and synthesis of the qualitative and quantitative results.



**Significant correlation at the .01 level for male respondents. (See Table 4.)

Figure 4. Scatter plots of GCM vs FCM for female and male survey respondents.

Response to the statement, "Engineering as a creative field." Means were computed from survey choices where the value labels were as follows: Strongly Disagree (1), Disagree (2), Neither Agree nor Disagree (3), Agree (4), Strongly Agree (5). Women responded with stronger agreement to the statement (women: mean = 3.73, men: mean = 3.67). Table 6 lists comparisons of means and standard deviations for different academic years in college and shows an increase in the agreement that engineering is a creative field as the female students proceeded through the engineering program, with the greatest agreement in the senior year of study. The male students showed an increase in agreement in the second and senior years, the agreement in the statement decreased in the junior year.

Table 6. *Comparison of Means for Year in School: Response to "Engineering is a creative field."*

	Year in School	Mean	n	Std. Deviation
Women	First Year	3.47	49	1.209
N = 192	Second Year	3.60	67	1.219
Mean = 3.73	Junior	3.82	55	1.056
S.D. = 1.141	Senior*	4.47	21	.827
Men	First Year	3.59	68	1.162
N= 210	Second Year	3.70	67	1.155
Mean = 3.67	Junior	3.61	62	1.121
S.D. = 1.123	Senior*	4.15	13	.707

*Includes co-op students, students in 5-year programs, etc.

Table 7. *Correlations for Female and Male Students: Response to the Statement, "Engineering is a creative field." Comparisons of GPA Range, CSE, GCM and FCM.*

			GPA	CSE	GCM	FCM
Women N = 197	Engineering is a creative field.	Pearson Correlation	-.034	.170*	.266**	-.092
		Sig. (2-tailed)	.634	.017	<.001	.198
Men N = 211	Engineering is a creative field.	Pearson Correlation	-.053	.193**	.190**	.093
		Sig. (2-tailed)	.446	.005	.006	.180

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Correlations of level of agreement with this statement and GPA range, CSE, GCM, and FCM depicted in Table 7, revealed that there was a positive correlation to this statement as CSE and GPA range increased for both women and men. There was a stronger positive correlation between the statement and CSE for the male students, where the correlation was at the 0.01 level for the men and at the 0.05 level for the women students. There was no correlation however, between the statement and GPA and FCM for either group.

Conclusions and Future Research

This study offered insight into differences and similarities of undergraduate women and men engineering students with respect to several parameters. The correlation data suggested that women students were less likely than male students to believe that creativity cannot be improved which is consistent with higher achieving students, who are more inclined to have a greater intrinsic motivation and a growth mindset [8], [9], [12], [39], [40], [41]. The average GPA range of the women was higher than that of the men, and higher than the average GPA range for engineering majors [8], [9]. Consistent with the literature that reports success in the engineering major leading to identification with the engineering major, this finding suggested that these women students had achieved success in the major [15]. An increase in both GPA and CSE positively correlated to an increase in GCM for both groups. This was consistent with the literature that as both success in the major increased as was indicated by GPA, and CSE increased, the belief that creativity can improved increased [8], [9], [12].

The significant difference in FCM between women and men, suggested that the men in this study had a stronger mindset than women that creativity is innate and cannot change. The positive correlation between CSE and FCM for the male students suggested that as CSE increased, the mindset that creative ability is innate and cannot change increased. This differed for the female students where there was no correlation between CSE and FCM. There was no correlation between GCM and FCM for women, but there was a positive correlation between GCM and FCM for the men, suggesting that as GCM increased so did FCM. This result, and both GCM and FCM having a positive correlation with CSE for the male students appear to be contradictory. Further analysis of the data that includes interviews, and synthesis of qualitative and quantitative results, and future research is necessary to better understand these findings.

The strongest agreement with the statement "Engineering is a creative field" was from both groups in the senior year, suggesting that an understanding of the connection between creativity and engineering was greatest in the last year of study. Progression in the major to the last year implies a success in the major and includes senior capstone projects [15]. Agreement with this statement increased in each year of study for the women students, suggesting that as identification with the engineering major and success in the major increased, the belief that engineering is a creative field increased as well. Agreement with the statement increased in the second year for men, upon completion of the first-year design experience, but decreased in the junior year. This suggested from the literature that the traditional curriculum of the middle years, and the level of rigor may have contributed to this drop [4], [8], [9], [24]. The mean GPA range of the women was higher than that of the men as well. This was consistent with the literature that as success in the engineering major increased, identification with the engineering major and the understanding of engineering as a creative field also increased [15]. Although there was no correlation between GPA range and CSE for either group, as CSE increased, the agreement with this statement that engineering is a creative field increased for both groups. Understanding the creative aspect of engineering aligns with identification with the major, and the belief that one has the capability to produce a creative product, which is characteristic of a higher CSE [8], [9], [15], [28], [29].

Analysis of the qualitative portion of this research and synthesis with the quantitative results will help to further explain the findings of this study. Future research relating to this study includes the following:

1. continue to interview undergraduate volunteers who completed the survey;
2. qualitatively analyze interview data and synthesize with quantitative results;
3. analyze valid survey responses from graduate students and engineers in the field;
4. interview volunteers from these groups; and
5. conduct survey with targeted recruitment of non-specific gender designations.

This research will help lead to a better understanding of the similarities and differences between women and men in engineering with respect to CSE, mindset and perspectives relating to creativity and engineering. The results of this research will contribute to the educational reform needed to assure that more female students enter engineering majors and succeed. This will help to cultivate a more diverse and innovative engineering workforce that will enhance the profession and positively impact society.

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