2018 ASEE Annual Conference & Exposition
Paper ID #23238

A Longitudinal Study Exploring Motivation Factors in Cornerstone and Capstone Design Courses

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Abstract

Design courses are an integral component of undergraduate engineering education. Design is recognized as one of the primary responsibilities of an engineer in industry. New designs are responsible for stimulating sales and company growth.[1] This paper presents the findings of a four year longitudinal study on the impact of motivation factors on course performance of mechanical engineering students in design courses. The first design course, cornerstone design, takes place during the first semester of freshman year. The second course, capstone design, takes place during the student's final year of undergraduate study. An adapted version of the Motivated Strategies for Learning Questionnaire (MSLQ) is used to measure five motivation factors: cognitive value, self-regulation, test/presentation anxiety, intrinsic value, and self-efficacy. Motivation is measured against the final grade in the course.

The major contribution of this paper is the ability to examine the impact of motivation on grades in design courses. The motivation and performance is also measured with regard to student gender, residency (domestic or international), family income, and highest degree attained by parents to determine if a correlation is realized.

Additionally, the study focuses on a single cohort of 32 students. This affords the ability for the examination of the differences in motivation between the students' freshman and senior year to determine if this can be correlated to student gender, residency (domestic or international), family income, and degree attained by parents.

The results of the study indicate that the student's freshman cornerstone design grades are impacted by their freshman anxiety levels with significance, which was further exacerbated by the student's residency. On the other hand, the senior capstone design grades were impacted by their intrinsic motivation. The change in their grade between their freshman and senior year was correlated to their freshman year anxiety and their residency, though the students exhibited similar levels of anxiety during their senior year.

Keywords

Senior Capstone Design, Freshman Cornerstone Design, Student Motivation, Engineering Retention

1. Introduction

Mechanical engineering is the largest engineering discipline, accounting for 23.8% of the bachelor's degrees awarded in 2016.[2] However, many studies have concluded that the majority of students that begin a degree in science, technology, engineering or mathematics (STEM) do not graduate from their respective field, with the six-year completion rate for STEM fields being less than 40%.[3,4] The demand for scientists and engineers is anticipated to continue growing with the demand for innovation. However, the output of STEM graduates is not estimated to grow at a comparable rate as the demand. Between 2015 and 2025, the United States is estimated to produce one million less STEM graduates than necessary to maintain our status as a technological leader.[5]

Academic success has been closely linked to the student's motivation.[6,7] A study by Busato, et.al found that achievement motivation was one of the most influential factors to academic success, alongside intellectual ability.[8] Moreover, intrinsic motivation factors have also been shown to greatly impact an individual's decision to pursue creativity and design.[9] Therefore, motivation is hypothesized to affect a students' drive and success in mechanical engineering design courses. Design courses are of particular interest here because many schools put an emphasis on cornerstone and capstone design. Further, many students who enter engineering fields site their eagerness to design and "take things apart" as motivation to pursue engineering. Universities have caught on to this and made design an integral part of their engineering curriculum. However, we have yet to study how students' motivation toward design changes between their freshman and senior year, specifically in their cornerstone and capstone design courses.

The goal of this study is to determine if motivation is correlated to student performance in design courses. This study uses longitudinal methods to examine a single cohort of students at the beginning and the end of their undergraduate tenure at Florida Institute of Technology. The initial observation is completed at the beginning of the students' freshman year, during their Introduction to Mechanical Engineering course. This is a design based course, introducing students to the design process and culminating with a group design project. The second observation is made in the students' Mechanical Engineering Design I course. This course is the first of a two semester sequence of senior design capstone. The goal is to identify changes in motivation with regards to course grade, also examining factors such as student gender, residency (domestic or international), family income, and degrees attained by parents. The study uses an adapted version of Pintrich's Motivated Strategies for Learning Questionnaire (MSLQ),[10] which will be detailed in a subsequent section of the paper.

The goal of this work is to determine if correlations exist between a student's motivational factors and their performance in mechanical engineering design courses. The motivational factors observed were the student's cognitive value, self-regulation, test/presentation anxiety, intrinsic value, and self-efficacy. The primary outcome of this research is to identify if general trends in students' motivational factors in design courses exist. If so, these trends can extrapolated and compared to the student's success to indicate whether such trends are a benefit or detriment to the student's success in the design course. Also, student motivational factors are observed with respect to the student's demographic information, including their gender, residency, and parent's education levels and income. Again, this information is used to determine if general trends in motivational factors exist for different demographic groups of students. Furthermore, this research could identify which of the five motivational factors are the most influential on the student's performance in each of the individual design courses. The educator can target specific factors for each student to have a very pointed approach in ensuring the success of the student, reforming design education.

An overarching outcome of this research is the ability to identify specific students that are more likely to underperform in design courses. The surveys were administered before the students were exposed to any of the material in the design course, making differences in curriculum between specific universities irrelevant. Therefore, by using a Motivated Strategies for Learning Questionnaire (MSLQ) that could be disseminated at the beginning of the semester, educators could determine the student's motivational factors and identify high risk students. The educator could then implement an intervention plan for that individual or group of individuals to ensure their success in the course. This study specifically addresses three research questions pertaining to the motivation of students in design courses.

> ***RQ1: Does a correlation exist between motivational factors and student success in Freshman Cornerstone Design?***
>
> ***RQ2: Does a correlation exist between motivational factors and student success in Senior Capstone Design?***
>
> ***RQ3: Does a correlation exist between changes in motivational factors and student success in Senior Capstone Design for the same cohort of students?***

2. Background

In this study, the authors use a modified version of the MSLQ survey as the instrument by which data is collected. This instrument is widely used in the engineering education research community for its ability to measure student motivation. It is hypothesized that there will be differences between genders, determining if our results align with prior research. Because Florida Institute of Technology has one of the highest international student body percentages in the country (34% of the total student body, 40% of the engineering student body), we are afforded an opportunity to seek out differences in motivation based on student residency. Family socialization is also considered here as we investigate the impact of factors such as family income on student motivation toward design.

2.1. Student Motivation

Pintrich identified two integral factors to motivation: ambition and learning.[11] The MSLQ is a self-assessment tool graded on a seven point Likert scale. The students rate the items between "not true to me" and "very true to me".[11] The five motivational factors examined in this study are cognitive value, self-regulation, test/presentation anxiety, intrinsic value, and self-efficacy. Cognitive value describes a student's ability to recognize the tasks required,[11] as well as the necessary sequence of tasks, in order to complete a goal. Self-regulation is the student's ability to structure oneself to complete a goal.[11] This differs from cognitive value as self-regulation is the ability to organize all necessary components to ensure completion of the given goal.

Test anxiety is the nervousness felt while taking an exam.[11] Similarly, presentation anxiety is the nervousness felt when giving a presentation to an audience. During the students' freshman year, the study targets test anxiety. This is due to the fact that the students are trying to adapt to the rigor of collegiate coursework and exams. However during the students' senior year, the study targets presentation anxiety. At Florida Institute of Technology, the students must complete a senior capstone design course during their senior year. One of the requirements for the course is a weekly presentation to the team's advisory board, which may include professors, graduate student advisors, or industry sponsors. This course presents the unique opportunity for students to give professional group presentations, which causes anxiety for some of the students that are unconfident in their public speaking skills.

Intrinsic motivation is the student's internal self-confidence and perception of the reasoning for their participation in a task or course.[11] This is synonymous with the student's interest in the task.[12] Self-efficacy is the student's confidence that he or she can achieve a goal. Self-efficacy is closely linked to expectancy,[10,11] which is the student's expectations for performance. Self-efficacy is not a global trait, as the student's self-confidence may increase or decrease depending on the task at hand.[12] Seymour and Hewitt identified one of the root causes of attrition from STEM majors as the loss of self-efficacy.[13] Once a student loses confidence in their ability to perform a task, they tend to feel uncomfortable or out of place. Similarly, Tinto identified that the most important factor in a student's academic performance is a measure that he termed "student commitment". This is a measure of the student's ability to integrate themselves into the academic community.[14,15] While there have since been many studies examining other contributing factors, the underlying tone in all of the research is the student's comfort, confidence, and motivation in their area of study.[14–17]

2.2. Student Gender

There exists an implicit bias that science, technology, engineering and mathematics (STEM) are masculine career fields. Though women make up around 50% of the college educated workforce, they account for only 29% of the STEM occupations.[18] Personal preference has been shown as the dominant reason women choose not to pursue STEM fields.[19] However, some women do initially choose to pursue a STEM field, but choose not to persist. Various research studies have shown that gender stereotypes are one of the driving factors behind attrition of women in STEM fields.[17]

Motivation studies typically compare gender differences between two aspects of motivation: mastery goals and performance goals.[20,21] The mastery goal is similar to intrinsic motivation and self-efficacy, as it is based off of an internal standard to achieve "mastery" of the subject.[20,22] Performance goals are the desire to showcase your ability to external sources. The mastery goal is very fluid, as it can change from task to task.[23] Research has suggested that adolescent females exhibit higher mastery goals, while males typically exhibit higher performance goals.[22,23] This can be detrimental for males if their focus shifts too heavily toward maintaining their public image rather than learning the material.[22] Females focus more heavily on mastery of the material to increase their self-efficacy perception over time.[22,24] However, females are also inherently exposed to a "stereotype threat". Stereotype threats are the feeling of judgement by peers based on societal stereotypes.[16,25] This phenomena causes students to fear doing poorly for the fact that they feel they may be thereafter defined by this stereotype.[16] This may cause students to "disidentify" with the field that they feel uncomfortable with, which is typically STEM related fields for females.[15,16,25] This is backed by the findings that women perform equally as well as men in math classes through middle school; however, men perform better in these subjects through high school and college, while women perform better in reading and writing.[26–28] Women leave STEM-based fields at 2.5 times the rate that men do once entering college.[25,29] One study also showed that self-identification and motivation factors can implicitly shift, which can improve or hinder overall performance.[30]

2.3. Student Residency

Of all of the bachelor's degrees awarded in 2016, only 9.6% were awarded to international students.[2] Two driving factors behind student success are academic integration and social integration.[31–33] Academic integration is the student's ability to succeed through the rigors of postsecondary coursework. Social integration describes the ability of the student to assimilate into their new environment and interact effectively with their university surroundings. For domestic students, this describes the acclimation into the university environment: being away from home, living alone or with other students, forming new friendships, maintaining long distance friendships, and interacting with professors. International students must not only acclimate to the university environment, but also to a brand new social environment. This could include difficulties such as language barriers and cultural differences.

Many studies affirm that social integration is one of the largest challenges for international students attending postsecondary education in the United States. There exists a culture shock regarding the requirement of specific social skills.[34] Abiding by new societal standards may be confusing or even offensive to the students depending on their previous residency and societal norm.[35] Language barriers present an obvious difficulty for the students. While the students may understand formal English and perform well on English proficiency exams, they may have difficulty understanding the colloquial English spoken in informal environments.[35,36] This can be especially problematic in a group environment, such as a project-based class like cornerstone or capstone design. The international students tend to take a peripheral approach rather than a central position.[36,37]

Braxton, Sullivan, and Johnson found that academic integration and social integration are interrelated concepts.[31] If the student is confident in their academic achievement, they are more likely to integrate in with their peers. Conversely, if a student assimilates well into the social environment, they are more likely to succeed in their studies.

One unique aspect of this study is the large international student population attending the Florida Institute of Technology. Generally, motivational studies have a small sample size of international students, observing largely domestic student populations. Studies that are specifically geared toward observing international students focus primarily on their first year retention, due to the high preliminary attrition rate surrounding social integration.

2.4. Family Socialization

In a similar regard as student residency, family socialization has been studied regarding its effects on postsecondary performance. Family socialization was studied by Tinto with factors including the parent's socioeconomic status, education, and expectations of the student.[32] While measured ability is the underlying factor of success and motivation to persist in college, success itself has been shown to correlate with family socialization; higher social status typically suggests a higher aptitude on standardized tests and entry exams.[38]

A study by the Tennessee College Association found that income is directly related to the persistence of students in university, with income affecting both transfer rates and permanent conclusion to university.[39] A more recent study indicated that socioeconomic status of the student's family affects the student's choice to attend postsecondary education. Even students with full intentions to attend university sometimes delay their attendance after performing a cost-benefit analysis.[40] This can also affect the student's decision to persist in university; especially if the student perceives themselves as performing poorly.

Aside from the economic concerns of attending university, the student's family's level of education and their expectations are also correlated to the student's motivation and likelihood of persistence. Defined by Tinto as "goal commitment", a student's likelihood of university attrition decreases as their commitment to achieving their goal increases.[38] Students that perceive a college degree as the societal norm are more likely to persist in their degree for fear of not meeting the expectations placed upon them. Families that have higher expectations of their students may also exhibit a higher interest in their education, offering more praise, support, and advice to the student.[38,41]

2.5. Design Courses

Formal design has been integrated into engineering curricula in one form or another. The common course sequence and terminology used today are "cornerstone design" courses to represent freshman design and "capstone design" to represent senior design. While many schools have also formally integrated design throughout the curriculum, most schools incorporate both cornerstone and capstone at the very minimum. Design courses are particularly useful because they allow students to transform their theoretical background knowledge into practical application.[42]

Necessary competences for design courses include technical drawing, CAD model generation, performing necessary analyses, and constructing a prototype or finished product.[42] This experience exposes the students to practices outside of the typical lecture based curriculum. Students need to consider the feasibility, practicality, and manufacturability of the design that is output.

Both capstone and cornerstones design courses are considered key design courses in formal engineering curriculum.[43] The courses are set up to incorporate an open-ended design approach and the skills necessary to output successful designs as a part of curriculum.[43]

2.5.1. Freshman Cornerstone Design

The importance of design courses has long been recognized and implemented in many senior level engineering curriculums, through the use of capstone design. However, universities are beginning to implement the design process earlier in the undergraduate curriculum in order to expose the students to one of the key aspects of engineering at the beginning of their degree. A survey revealed that one of the reasons for high attrition rates in engineering was due to freshmen students' inability to connect their college coursework to their engineering career.[44] To address this, cornerstone design courses have been introduced to present an introductory-type design course to show students how engineering allows you to go from designing a system to building one.

The impact of cornerstone design courses has reached beyond education, as industry partners wanted a stake of what students were learning. Industry yearned for students to gain skills in problem solving, critical thinking, and communication within a team format at an earlier stage in their education.[45]

Cornerstone and capstone design courses are opportunities for students to develop teamwork skills and improve communication and management skills.[46] The cornerstone course focuses on developing student's skills in identifying the problems and needs of customers and working to find a solution through a final design or product.[47] The aim of the cornerstone course is to help students develop the fundamental skills required in engineering, including analyzing data, generating results, and using a systematic approach to designing.[48]

2.5.2. Senior Capstone Design

Senior capstone design is one of the final requirements for graduation at many engineering universities in the United States. The course can be a single semester, or can bridge between two or even three semesters of study.[49,50] Senior capstone design is typically the students' first exposures to applied engineering design work, similar to what they would experience in industry. Aside from taking an engineering challenge from design to fruition, the students also gain important skills- presentation, technical writing, and business skills that are not taught throughout the traditional engineering curriculum.[51]

The goal of senior capstone design is to prepare students with these skills, as well as communication, team work, and project management skills through a team based design experience.[52] For most students enrolled in an engineering program in the U.S., senior capstone design courses are mandatory for graduation as they are a requirement by various accreditation bodies, such as ABET.[53] This course allows students to use their knowledge and skills acquired throughout their previous three years of engineering coursework to produce a useful product or design.[54] In many instances, the course is advertised as a bridge between college curriculum and industry work.[54]

Student projects are typically monodisciplinary and can range from competition based projects, university sponsored projects, or industry sponsored projects.[55–57] However, some universities also feature interdisciplinary project teams. Interdisciplinary teams offer the benefit of a wide multitude of competencies. Studies have shown that interdisciplinary project teams produce better solutions than monodisciplinary teams.[55]

Senior design culminates with the presentation of the project deliverables, as well as an expo or open house to showcase the student's projects.[55] The project deliverables may include a technical report detailing the design process used, a presentation to an advisory committee including project sponsors, and the final design or product.[56,58,59]

3. Research Method

The case study was conducted longitudinally, with data obtained at two points in time – students' freshman cornerstone course and senior capstone course. The MSLQ was disseminated during the

Fall Introduction to Mechanical Engineering course taught at Florida Institute of Technology. This is a first-semester, freshman level course. The second set of data was collected in the Fall Mechanical Engineering Design I course. This is a two semester capstone course taking place during the students' senior year. The data was obtained in the first of the two semesters. In theory, the same cohort of students enrolled in the freshman level cornerstone course were seniors in their capstone course; this would satisfy a standard, four year trajectory with the students graduating in May 2018.

3.1. Study Subjects

The data collected for the freshman analysis was obtained in the fall semester of the students' freshman year in their Introduction to Mechanical Engineering course. This data is collected during the second week of classes, before students have begun their design projects. The demographic information for these students is provided in Table 1. The freshman year students were 86.7% male and 13.3% female. Approximately 48% of the population are domestic students, while 52% are international students.

Table 1: Freshman Demographic Information

	Domestic	International	**Total**
Males	39	46	85
Females	8	5	13
Total	**47**	**51**	**98**

The data for capstone design was obtained in the fall semester of the students' senior year in their Mechanical Engineering Design 1 course. The data was collected during the second week of classes. However, the students -at this point- were already introduced to their project, but had yet to start working on it. Students were provided a brief problem statement describing the challenge they were tasked with addressing. There are a total of 88 students participating in the senior capstone design course. The demographic information for these students is provided in Table 2. The senior population is 87.5% male and 12.5% female. About 40% of the population are domestic students, while 60% of the seniors are international students.

Table 2: Senior Demographic Information

	Domestic	International	**Total**
Males	28	49	77
Females	7	4	11
Total	**35**	**53**	**88**

To normalize the result and follow the same cohort of students from freshman to senior year, all of the outliers were eliminated for the analysis. Effectively, this study only considered common students between the cornerstone and capstone course. The demographic information for the students of interest in the study is provided in Table 3. In the normalized cohort of students, 91% are male and 9% are female. Moreover, the domestic population of students is larger than the international population: 56% and 44%, respectively.

Table 3: Cohort Demographic Information

	Domestic	International	**Total**
Males	15	14	29
Females	3	0	3
Total	**18**	**14**	**32**

3.2. Analysis Performed

The analysis performed here will investigate three different phenomena, each to address the research questions posed. First, we determine what motivational factors contribute to success (as measured by course grade) in freshman cornerstone design. Second, we perform a similar analysis for senior capstone design to determine if student motivation toward design is different in freshman design than it is in senior design. The cornerstone and capstone design grades are compared to the five motivational factors, taking the student's demographic information into account. Finally, we determine if changes in student motivation from freshman to senior year correlate to how students perform in their design courses. The delta in the cornerstone and capstone design grades are then compared to the changes in the five motivational factors, also with regard to the student's demographic information. Each of the aforementioned analyses will be compared to the student's gender, residency, and family socialization to determine if correlations exist in those domains as well. Ultimately, the primary goal of the analysis (RQ1 and RQ2) is to determine if and which of the factors correlate to the student's performance in design courses. The secondary goal (RQ3) is to determine if the change in the student's performance has any correlation to their change in motivation throughout their undergraduate tenure.

Two statistical analysis types are performed to correlate and compare student motivation and performance: linear regression and t-tests. A linear regression is utilized to determine if a correlation exists between a set of independent variables to the dependent variable. Since multiple variables are present and the correlation could exist at a multi-level order, we consider Akaike's Information Criterion (AIC) to find the best fit model. This allows us to analyze all linear regression model permutations to find the model with the best fit. A paired t-test is performed since only the common students from both the cornerstone and capstone design courses are analyzed. In the results, $\alpha < 0.05$ is considered as significant, however $\alpha < 0.10$ is maintained for discussion.

4. Results

Recall the five motivational factors examined were the student's cognitive value, self-regulation, test/presentation anxiety, intrinsic value, and self-efficacy. The student's demographic information was also used as a parameter of interest, including their gender, residency, parent's highest educational attainment, and family income.

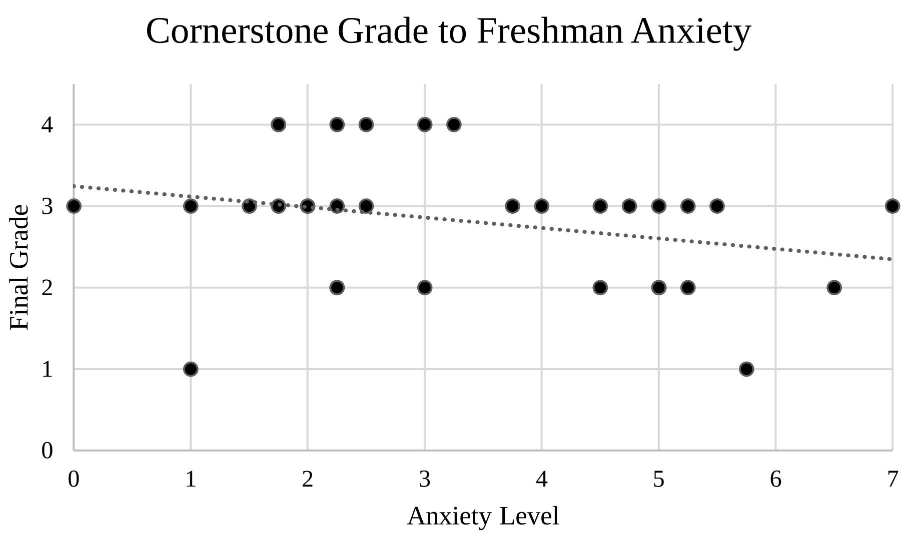
Using the MSLQ, each of the students in the study self-reported their motivation levels, using a Likert scale of 1-7, where 1 indicates that the question is "not true to me" and a 7 indicates that the question is "very true to me". Each of the grades obtained were correlated to a numeric value as shown in Table 4, below. This is the same scale that is used by Florida Institute of Technology to determine the student's grade point averages. Therefore, a grade of 4 signifies an A.

Table 4: Numeric Grade Values

Student Grade	Numeric Value Assigned
A	4
B	3
C	2
D	1
F	0

4.1. Motivation in Freshman Cornerstone Design

For each of the students examined, a linear regression was performed to determine which of the five factors correlated to the student's performance (measured using their final grade in the course). The AIC analysis determined that Anxiety and Residency had the greatest correlation to student performance in the cornerstone course (model p-value = 0.08769). The student's finals grades were found to be negatively impacted by the student's anxiety levels. Figure 1 shows the correlation between the student's self-reported anxiety and their performance in the course.



	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	3.57553	0.36173	9.885	8.58E-11
Freshman Anxiety	-0.15416	0.08048	-1.916	0.0653
Residency	-0.45919	0.28187	-1.629	0.1141

Residual standard error: 0.7801
F-statistic: 2.65
Model p-value: 0.08769

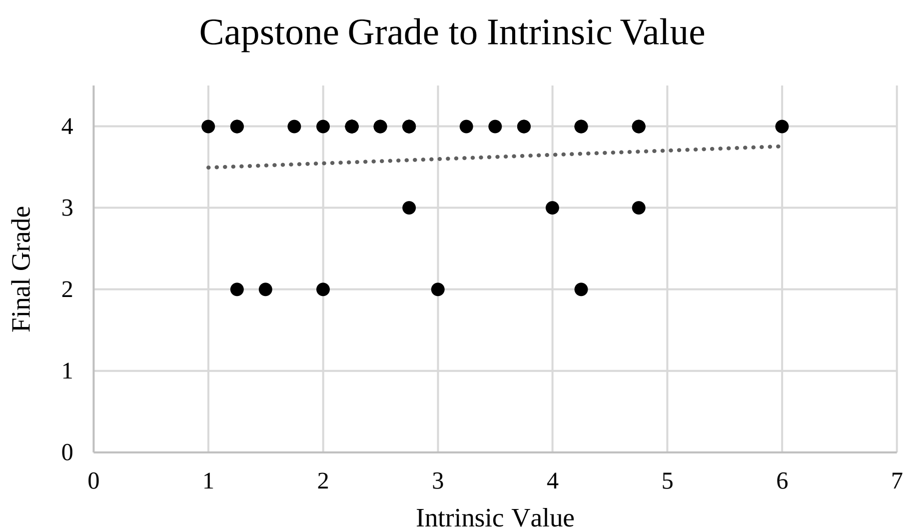
Figure 1: Cornerstone Grade vs. Freshman Anxiety Levels

It is observed that students who possessed lower levels of anxiety earned higher grades in the course. It is interesting to note that the MSLQ was disseminated at the very beginning of the cornerstone design course, before the students had submitted any assignments. Thus, there were students who, prior to any course relevant assignments, possessed higher levels of anxiety.

The correlation between the student's performance and their anxiety levels was found to be further exacerbated by their residency. The international student population exhibited higher levels of anxiety at the beginning of the course than the domestic students.

4.2. Motivation in Senior Capstone Design

An AIC analysis is likewise performed for senior students in their capstone course. The AIC analysis determined that Intrinsic Value possessed the most statistically significant correlation to student grades, as shown graphically in Figure 2. Students exhibiting a higher intrinsic value tended to perform better in the senior capstone course. The intrinsic value of the students was not impacted by any of the student's demographic information, such as residency or gender. Similar to the freshman cornerstone case, the MSLQ was disseminated to the senior students early during their first semester of capstone design.



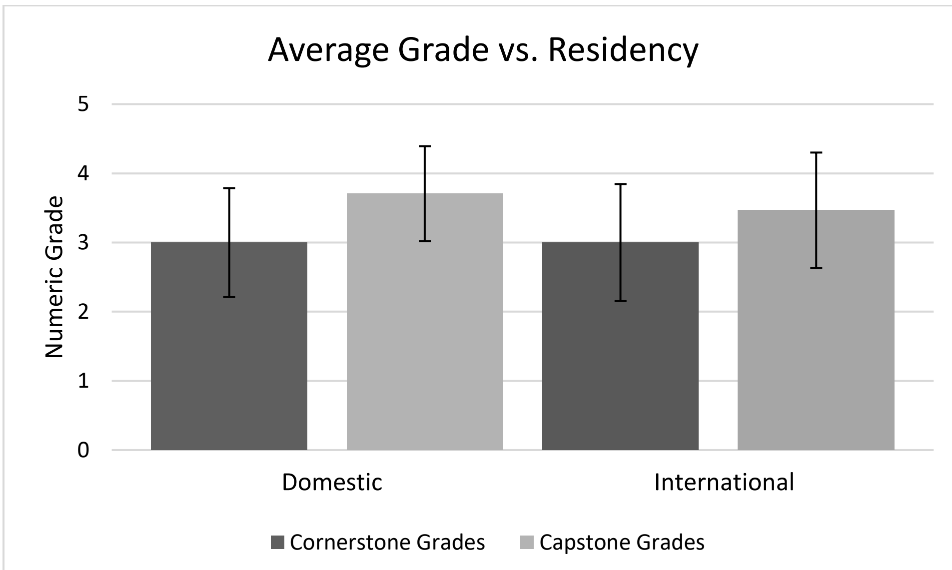
	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-0.5174	1.1795	-0.439	0.66405
Intrinsic Value	0.6678	0.1907	3.502	0.00147

Residual standard error: 0.6475
F-statistic: 12.26
Model p-value: 0.001469

Figure 2: Capstone Grade vs. Senior Intrinsic Value

4.3. Changes in Performance and Motivation in Design Courses

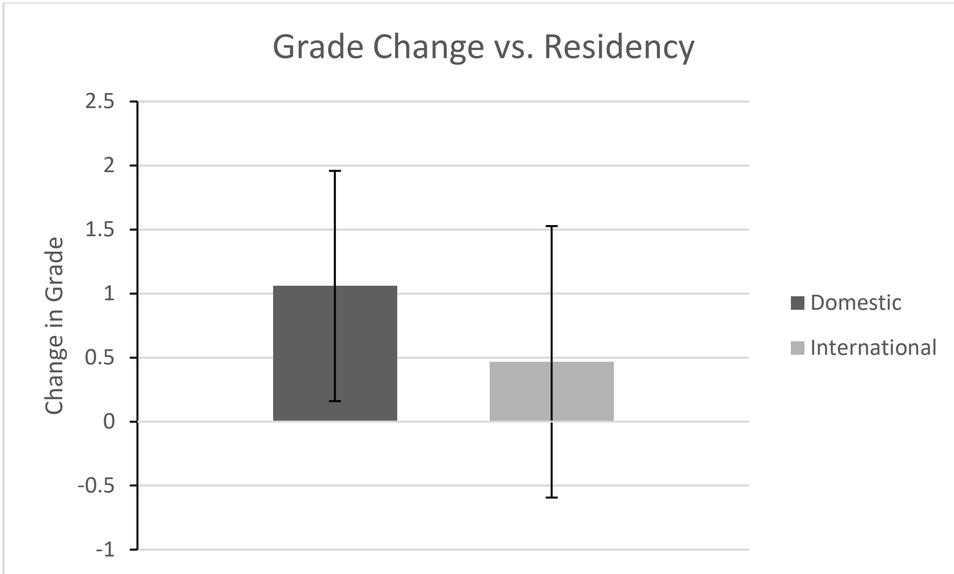
The student's change in performance is examined with respect to the student's demographic information, freshman year motivation factors, senior year motivation factors, and calculated deltas in motivation levels between the student's freshman design course and senior design course. The student's change in grade was correlated to the student's residency (domestic or international student), however there is minimal correlation realized between changes in motivation factors to changes in grade. Rather, it is realized that residency was most correlated to changes in performance. Consider Figure 3, which illustrates the grades of domestic and international students in the cornerstone and capstone courses.



	International	Domestic
Freshman Cornerstone	3.00 ± 0.845	3.00 ± 0.789
Senior Capstone	3.47 ± 0.834	3.71 ± 0.686

Figure 3: Cornerstone and Capstone Design Grades for International and Domestic Students

When comparing the differences in students over the course of the four years, the domestic students generally make more improvements than their international counterpart. As seen in Figure 4, the domestic population made greater strides in improving their grades between cornerstone and capstone, compared to international students.



	International	Domestic
Change in course grades	0.46 ± 1.061	1.06 ± 0.899

Figure 4: Longitudinal Changes in International and Domestic Student Grades

4.4. Longitudinal Comparisons

Since the same cohort of students is measured both during their freshman cornerstone and senior capstone courses, t-tests are performed on their response data to determine if significant changes are encountered in their motivational factors. Again, this data only considers the students who completed the survey during both their freshman and their senior year (n=32). As shown in Table 5, the average anxiety of the senior class only decreased slightly from that of the freshman class.

Table 5: Anxiety Paired T-Test Results

Anxiety	Freshman	Senior
Mean	3.37	2.92
Standard Deviation	1.7757	1.2402
Pearson Correlation	0.1352	
t Stat	1.2447	
p-value	0.2226	
t Critical	2.0395	

The anxiety levels decreased about 0.44 points during senior year, but this is not found to be statistically significant ($p = 0.22$). On the other hand, the student's intrinsic motivation showed a significant increase between their freshman and senior year design courses, as shown in Table 6. The average intrinsic value increased over 0.65 points, with a significance value of $p<0.01$.

Table 6: Intrinsic Value Paired T-Test Results

Intrinsic Value	Freshman	Senior
Mean	5.50	6.16
Standard Deviation	1.2706	0.6097
Pearson Correlation	0.2120	
t Stat	-2.8832	
p-value	0.0071	
t Critical	2.0395	

5. Discussion

Three findings are presented in this research that are unique and could benefit the engineering education community. Freshman Cornerstone, Senior Capstone, and changes between both design courses are presented. Moreover, a discussion of the general motivational differences between freshman cornerstone and senior capstone is presented.

5.1. Freshman Performance and Anxiety

The freshman design student's performance was found to be significantly impacted by their anxiety levels starting out their degree program to a significance of $p<0.1$. One such study found that inadequate preparation in high school affected 40% of STEM students.[29] This lack of preparation could increase the student's anxiety entering university, affecting their performance. The performance and anxiety was found to be further exacerbated by their residency. Namely, international students exhibited higher levels of anxiety in the design course than the domestic students. As previously outlined, this could be due to their transition into not only university life, but also into a whole new cultural experience. The students feel a higher level of anxiety having to integrate into their environment academically, as well as socially.

Also, the Cornerstone design course at Florida Institute of Technology is conducted in a team environment, featuring multiple mini group projects relating to the material throughout the course. Some international students do not have previous exposure to group projects when entering a U.S. institution. A study conducted at Newcastle University observed first year, international engineering students through their design project experience. 67% of the students observed indicated that their previous schooling did not encourage group work, rather it was intended to be an individual effort in a competitive environment.[36] While most of the international students surveyed indicated the group project environment was beneficial to their learning, some noted difficulties that led to a negative project experience; these included feelings of exclusion, language barriers, and self-critique.[36]

In addressing the first research question (RQ1: Does a correlation exist between motivational factors and student success in Freshman Cornerstone Design?), we find that a negative correlation does exist between student success and anxiety in freshman engineering. This relationship is further exacerbated when considering international students.

5.2. Senior Performance and Intrinsic Value

Senior capstone design students were found to be significantly impacted by their intrinsic value with a $p\text{-value} < 0.005$. Recall, a student's intrinsic value exhibits their self-confidence in the task at hand, as well as their dedication or drive to perform well at the task. In other words, intrinsic value can also indicate the student's recognition of the significance of the task and their reasoning for partaking in the task. Students with higher intrinsic motivation values at the beginning of their capstone design project performed better throughout the course of the semester than students with lower levels of intrinsic motivation. The students that recognized the importance of the design course tended to have higher grades than the other students.

Another interesting finding lies in the fact that the senior level students are not impacted by anxiety. Capstone design courses are widely recognized as the culmination of the student's undergraduate degree. The course requires a year-long dedication to a single project, from the ideation and design to the final deliverable products. Capstone is structured to emulate a real-world, industry position. However, rather than exhibiting high levels of anxiety at the beginning of their capstone design course, the students exhibited high levels of intrinsic motivation. This demonstrates that the students are confident in their abilities towards the task at hand, as well as their abilities as a graduate mechanical engineer.

Also, the student's senior capstone design performance was not impacted by their residency. This indicates that the international students may have become more comfortable with the idea of working in a group environment on a project, or feel more comfortable in their social setting over time, allowing them to showcase their academic skills without anxiety. Therefore their motivation is not impacted by their success in the course. This illustrates that generally, by senior year, students have matured to allow their intrinsic value to control their success, not allow their anxiety to overcome them.

In addressing the second research question (RQ2: Does a correlation exist between motivational factors and student success in Senior Capstone Design?), we find a positive correlation exists between intrinsic motivation and student success. Moreover, the domestic versus international student differences (whereby anxiety was exacerbated for international students) observed in the first research question do not exist in this question.

5.3. Changes in Performance and Motivation

The change in the student's performance throughout their student design courses was found to be impacted by their residency as opposed to any specific motivational factors. While the t-tests do show some interesting findings that could explain this phenomenon, the third research question (RQ3: Does a correlation exist between changes in motivational factors and student success in Senior Capstone Design for the same cohort of students?) has identified that no motivational factor changes correlate to changes in student success between both courses. However, in retrospect, the authors realize that this is a multidimensional problem, and so many changes occur for a student between freshman and senior year that it cannot be left to motivation alone to realize a correlation. Further, the course expectations were different, course instructors were different, and students who made it to capstone design survived the rigors of engineering curriculum. Thus, changes in motivation could almost be expected, but do not necessarily have to correlate to the changes experienced in course performance.

Ultimately, we aim to use this data to improve retention and persistence in engineering. However we recognize that retention is a multi-dimensional phenomena that could be influenced by initial motivation, changes in motivation, and final motivation within the motivation sphere. Further, there are other dimensions that could influence retention that we are not considering here.

5.4. T-Test Comparison

During cornerstone design, the students' grades are highly correlated to the students' anxiety levels, whereas in capstone design the students' grades are highly correlated to their intrinsic values and views on the contribution of the course to their learning endeavors. In examining this further, the t-tests revealed that student anxiety decreased (though not statistically significant) and intrinsic motivation increased (statistically significant). Best explained, there is an unusual paradigm shift whereby student anxiety does not significantly decrease, but students allow their performance to be dictated by their intrinsic motivation rather than their anxiety. While the students stay anxious regarding the design effort, their confidence prevents the anxiety from impacting their performance. This happens so much so that, while anxiety does not decrease between the start of cornerstone design and the start of senior design, their intrinsic value takes over.

A model by Tobias made an interesting observation regarding changes in anxiety. Tobias found that students with higher anxiety performed more poorly due to the anxiety interfering with their ability to retrieve the necessary information. However, students exhibiting higher cognitive values combat this anxiety and prevent the anxiety from interfering with their performance.[12,60] To explore this, Table 7 shows the student's increase in cognitive value was significant to $p<0.05$.

Table 7: Cognitive Value Paired T-Test Results

Cognitive Value	*Freshman*	*Senior*
Mean	4.88	5.17
Standard Deviation	0.6545	0.6372
Pearson Correlation	0.2734	
t Stat	-2.0948	
p-value	0.0445	
t Critical	2.0395	

Pintrich found that students with higher anxiety levels exhibited lower cognitive values.[12] However, higher cognitive ability did not directly result in higher performance. Rather, the student needed to have a high cognitive ability and the intrinsic motivation to properly apply the cognition.[10,12]

Though the student's anxiety does not significantly change between the start of freshman and senior capstone, the student's cognitive and intrinsic values were shown to increase with significance. The combination of these two factors could combat the student's anxiety, allowing their performance to increase.

5.5. Limitations of the Study

One of the primary limitations of the study is the fact that data was only obtained at two instances in time. This is sufficient in examining the correlation between motivation and course performance in each of the design courses, as well as the change in motivation levels of a single student between their respective freshman and senior year; however this does create some ambiguity for students that do not follow the standard trajectory. For example, while the students did not exhibit a significant change in anxiety in their freshman or senior design courses, their anxiety may have altered significantly throughout the course of their time at the university.

Another limitation is the ability to follow the students through the degree program. Of the students that began their mechanical engineering degree when freshman fall data was collected, only 32 of them followed the standard trajectory of four year completion. Nine of the students completed senior design in the previous school year, two completed senior design in two years prior to the normal trajectory. The remaining 32 of the students are currently underclassmen (taking more than the standard four years to complete the degree) or have transferred to a different major, and 23 of the students are no longer enrolled at the university. This is summarized in Table 8.

Table 8: Freshman Student Statistics

Senior Capstone Attendance	Number of Students
Standard Projection (Data Collected)	32
One year ahead	9
Two years ahead	2
Underclassmen	32
No longer enrolled	23

The senior class is a similar situation. There are 88 total seniors enrolled in senior capstone design, with the 32 that followed the standard trajectory. However, it is ambiguous as to whether the anomalies were freshmen at the university at a different instance in time or if they were transfer students at something other than the freshman level. This would provide insight on the impact of motivation on overall performance, as well as retention or attrition of students from mechanical engineering at Florida Institute of Technology.

6. Conclusion

This longitudinal study examines students' motivation toward design in their cornerstone and capstone design courses to determine if any motivational factors correlate to student performance in the course. This study was performed by administering the MSLQ survey two weeks into the students' freshman and senior year design courses. The study identifies that in freshman cornerstone classes, student performance correlates significantly to anxiety, whereby students with higher anxiety performed more poorly than those without. Conversely, in senior capstone design, student performance is correlated to intrinsic motivation. The study also sought out correlation between changes in student performance in their respective cornerstone and capstone design courses to changes in motivational factors. T-tests performed reveal that students experience a shift in motivation between their freshman and senior year whereby anxiety plays less of a role in performance and intrinsic value dominates.

6.1. Future Work

Future work in this study includes collecting data yearly for each level of university (e.g. freshman, sophomore, junior, and senior data). The ability to analyze the deltas in motivation between each year of university study would allow for the extrapolation of trends to determine if motivation has an effect on overall performance and student retention. Student performance is a contributing factor to student retention, therefore the ability to realize trends would allow for intervention plans to be implemented to improve the likelihood of retention for high risk students. Including the data obtained from the freshman and senior students that did not follow the standard trajectory (and therefore were not included in this analysis) could also provide some interesting insight into the performance and motivation of persisters compared to the non persisters.

Additional future work includes the implementation of a qualitative survey to supplement the quantitative scores. This can be achieved through the use of an interview, where the students are encouraged to expand upon the MSLQ or justify some of their qualitative answers. This would allow the researchers to gain further insight into the strengths or weaknesses of specific students, and correlate these to their MSLQ values.

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