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Examining the Impact of Student Motivation on Performance in Mechanical Engineering Design Courses

by

Elisabeth Kames

A dissertation submitted to the College of Engineering and Science of Florida Institute of Technology in partial fulfillment of the requirements for the degree of

> Doctor of Philosophy in Mechanical Engineering

Melbourne, Florida May, 2020 We the undersigned committee hereby approve the attached thesis, "Examining the Impact of Student Motivation on Performance in Mechanical Engineering Design Courses," by Elisabeth Kames.

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Abstract

Title: Examining the Impact of Student Motivation on Performance in Mechanical Engineering Design Courses

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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 dissertation outlines a study seeking to explore the impact of student 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, which is used as the performance metric.

The major contribution of this research is the ability to examine the impact of motivation on performance in design courses. The motivation and performance is also measured against student demographic information 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 longitudinal study focuses on a single cohorts of 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 indicate that motivation is a key factor in the students' performance in design curriculum. All five of the motivation factors are found to impact the students' performance; however, different motivation factors are found to impact the students' performance at different points in time. This proves the multidimensional and dynamic nature of motivation. The quantitative findings are further explored through qualitative data analysis to explore variables impacting the students' motivation and performance throughout their capstone design sequence. A total of 69 unique codes were identified through the student interviews, providing useful feedback on student experiences in senior capstone design at Florida Institute of Technology.

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Dedication

Dedicated to the memory of Kenneth Michael "Peep" Dixon who was always one of my biggest supporters and believed in me when I didn't know how to believe in myself. You were, and continue to be, an inspiration to me that makes this journey possible.

"We gettin' an island."

Chapter 1 Importance of Design Education

Engineering curriculum at the university level typically culminates in a senior design capstone course. The goal of the senior capstone design course is to challenge the students with an example of a real-world project, preparing them for industry. While the essence of senior capstone design has been dated back to the late 18th and early 19th centuries, these courses began to resurface in the 1970's. However, their significance in the curriculum went unrecognized, with approximately 3% of American institutions offering a formalized design curriculum.² University curricula used to focus heavily on design and design challenges, typical of industry level engineering. Due to increasing system complexity, engineering curricula were prompted to add more science and mathematics classes to help students understand needed tools and methods.³ However, over time this produced students with a decreasing understanding of the practical applications of engineering and design.³ The reintroduction of modern day senior capstone design in the 1980's and 1990's served to bring the practical application of technical topics back to university level engineering.^{4,5} It was recently identified that corporations also yearned for students entering industry to have a greater understanding of problem solving, critical thinking, and presentation and communication skills.⁶ Senior capstone design serves as a transition from compartmentalized learning experienced in introductory level engineering

courses to the design and application desired by students entering industry. ⁴ It is typically the student's first exposure to team- and project- based engineering similar to what they will experience as a professional engineer. Its importance has been emphasized by accreditation bureaus such as the Accreditation Board for Engineering and Technology, Inc. (ABET).^{4,7}

Many studies have observed motivation as a predictor of academic performance.^{8–} ¹⁰ Busato, *et al.*, identified that motivation and intellectual ability were the two key indicators of academic success at the university level.¹⁰ Pintrich implemented the Motivated Strategies for Learning Questionnaire (MSLQ) to measure student motivation levels and hypothesized their importance for academic performance.¹¹ Intrinsic motivation factors have been closely linked to design thinking and creativity in designing.¹² It is hypothesized that motivation factors impact student performance in design courses and ultimately their success.

This dissertation seeks to identify the link between student motivation and performance in design courses. Design courses are of particular interest here because many schools put an emphasis on them. Further, many students who enter engineering fields cite their eagerness to design and build products 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 design courses. This study presents insight into the correlation between motivation and student performance in design courses. The study uses longitudinal methods to examine a 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 observations are made in the students' Mechanical Engineering Design I and Mechanical Engineering Design II courses. These two courses account for the yearlong senior design capstone. The changes in student motivation is observed with regards to course grade, also examining factors such as student gender, residency (domestic or international), family income, degrees attained by parents, and previous academic performance—including transfer status and grade point average (GPA). The study uses an adapted version of Pintrich's Motivated Strategies for Learning Questionnaire (MSLQ),¹³ which will be detailed in a subsequent section.

The motivational factors observed were the student's cognitive value, selfregulation, test/presentation anxiety, intrinsic value, and self-efficacy. The primary outcome of the research identifies general trends in students' motivational factors in design courses exist. These trends are then 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 motivation 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 identifies which of the five motivational factors are the most influential on the student's performance in each of the individual design courses. This may assist educators in targeting specific factors for each student to have a very pointed approach in ensuring the success of the student, reforming design education.

An overarching goal of this research is the ability to identify specific students that are more likely to underperform in design courses. Two of the three total surveys were administered before the students were exposed to any of the material in the design course, making differences in design 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.

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.¹⁴

Necessary competencies for design courses include technical drawing, CAD model generation, performing necessary analyses, and constructing a prototype or finished product.¹⁴ 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 generated.

Both capstone and cornerstones design courses are considered key design courses in the formal engineering curriculum.¹⁵ The courses are set up to incorporate an openended design approach and the skills necessary to output successful designs as a part of curriculum.¹⁵

Freshman Cornerstone Design

The importance of design courses has long been recognized and implemented in many senior level engineering curricula, through the use of capstone design. However, universities are recently 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.¹⁶ To address this, cornerstone design courses have been introduced to present an introductory 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.⁶

Cornerstone and capstone design courses are opportunities for students to develop teamwork skills and improve communication and management skills.¹⁷ 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.¹⁸ 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.¹⁹

Freshman Cornerstone Design at Florida Institute of Technology

At Florida Institute of Technology, the mechanical engineering freshman cornerstone design course is called Introduction to Mechanical Engineering. In this course, the students are taught the basics of engineering, such as engineering drawing, tolerancing, computer aided design (CAD), and analysis. The student are also exposed to two different design projects. The design projects follow the two types of engineering design: forward and reverse engineering. The reverse engineering project is the first of the two that the students complete, and the curriculum taught during this time directly relates to the project that the students are working on. The student groups buy inexpensive consumer products – such as a hair dryer, printer or tools – and are instructed to analyze the product, identify a design flaw, and propose a solution to the problem. The students are expected to generate function models, assembly trees, morphological charts, and process diagrams for the system. The second design project, the forward engineering project, is an entrepreneurial and innovative project in which the students are given an open-ended design prompt. They are not provided with a problem statement, rather they are provided with a problem scenario. The students are expected to address this problem scenario by composing a proposal for approval, generate a problem statement, formulate a solution, and build a mockup or prototype of their solution.

Senior Capstone Design

Senior capstone design is one of the final requirements for graduation at many engineering universities in the United States. Senior capstone design has been regarded as the pinnacle of an undergraduate's engineering education. The format of senior capstone design differs between universities. The course can be a single semester, or can bridge between two or even three semesters of study.^{4,20} Senior capstone design is typically the students' first exposure 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.²¹

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.²² 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.⁷ 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.²³ In many instances, the course is advertised as a bridge between the college curriculum and industry work.²³

Student projects are typically monodisciplinary and can range from competitionbased projects, university-sponsored projects, or industry-sponsored projects.^{24–26} 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.²⁴

Senior design culminates with the presentation of the project deliverables, as well as an expo or open house to showcase the student's projects.²⁴ 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.^{3,25,27}

Senior Capstone Design at Florida Institute of Technology

Senior capstone design serves to prepare students for industry by bringing practical application of design back to the university level. At Florida Institute of Technology, senior capstone design is a final requirement before graduation from undergraduate engineering curriculum. The course is a three semester sequence, preparing students for industry. The first course, Design Methodologies, takes place during the student's spring semester of their junior year. This course is intended to equip the students with all of the skills and considerations necessary to complete their senior capstone design projects. The course overviews the basics of the design process, the preparation of technical reports and presentations, and different problem-solving methodologies.²⁵ The students are assigned three miniature group projects to introduce them to project-based course requirements and allow them to employ the skills they are learning at the time. Design Methodologies culminates with the students being assigned their senior capstone design projects and teams. The second course in the sequence is Mechanical Engineering Design 1. This course takes place during the fall semester of the student's senior year and is the first of the two

semesters in which the students work on their senior projects. The fall semester focuses on the design and analysis of the chosen solution. The students formulate their solution, generate hand and CAD drawings of the full system and sub-systems, and perform calculations and computer-based analyses on their systems to guarantee it meets all designated requirements for the project. The final course in the sequence, Mechanical Engineering Design 2, requires the students to complete any supplementary analyses, build and test the prototype of their system, and manufacture a final solution. The course concludes with a design showcase of all of the final products.

The projects at Florida Institute of Technology fall into one of three major categories: industry-sponsored, competition, or humanitarian projects. The industrysponsored projects are provided to the university by an industry sponsor and allow the students to experience "real-world" engineering. The competition projects include the Society of Automotive Engineers (SAE) Baja and Formula competitions, and the Dragster Car project. The humanitarian projects are generated based on a need as designated by the student teams themselves. Some previous examples include a manually operated water purifying device and a machine to manufacture shoes from old plastic bottles for third world countries.

Aside from focusing on the design and build of their senior capstone design projects, the students are also required to submit weekly executive summaries and presentations to their advisory committee throughout both semesters of their Mechanical Engineering Design course; the committee is comprised of the course professor, graduate student assistants (GSAs), and industry or university sponsors.^{3,25,27,28} The weekly presentations are given to ensure the project health, as well as to provide the students with a platform to practice their presentation skills in a semi-formal environment and prepare for their formal presentations. The end of the student's fall and spring semesters of senior year culminate in a Preliminary Design Review (PDR) and Critical Design Review (CDR), respectively. Each of these milestones require the students to submit a technical report outlining their design and processes, and a comprehensive presentation to their advisory boards.

Intellectual Merit

The intellectual merit of this research lies in the ability to identify critical motivation constructs of students in design education and equate this motivation to their respective performance. While many studies have examined the importance of motivation to performance in academia, this research seeks to specifically address the motivation and performance of students in engineering design courses. The design courses examined offer a project-based learning experience for the students, similar to the experience they would have as a design engineer in industry.

Educators face challenges due to the diversity of the student population and the diversity of knowledge from student to student. Students have different learning styles and different motivation and attitudes toward education and learning. This requires educators to adapt to the population in the course they are teaching. The ability to examine student motivation and understand the factors driving the student performance allows for educators to tailor their courses to provide a positive learning experience for the students. The correlations found from this research could also provide educators with the ability to

identify students that are likely to underperform in their course and develop an intervention plan for those students.

Broader Impact

The impact of understanding the influence of a student's motivation on their performance in mechanical engineering design courses affects the education and the research community, as well as industry.

Education: Design courses are an integral component of undergraduate engineering education. Senior design capstone has been described as a defining moment in an undergraduate's education, representing the transition from compartmentalized, backof-the-book learning to applying a broad range of concepts to complete a design challenge; this is similar to what is expected of engineering graduates once they get to industry. Freshman cornerstone design is a newer course being implemented into the engineering curriculum due to a recognized need to expose engineering students to design earlier in their undergraduate education. The ability to identify motivation factors that contribute to student success in design courses allows for the overall improvement of the design curriculum at the collegiate level. This also allows educators to identify students that may be less likely to succeed or persist, and implement an intervention plan to assist the student in accomplishing their goals.

<u>Research</u>: By using computational analysis tools, we can both understand and predict student persistence in engineering. Due to the number of students analyzed, number and type of variables, and factors that contribute to student persistence, it was important to explore various computational approaches. These approaches include, but are not limited to: regression models and machine learning. This is used to determine which factors contribute to engineering persistence, as well as when the factors contribute the most.

By examining this, we are able to make changes in how, who and when we recruit students in engineering to increase their persistence. Moreover, we determine underlying factors that contribute to underrepresented minorities' enrollment in STEM fields.

<u>Industry</u>: Design courses are the first formal exposure that engineering students have to an industrial application of the design process. Identifying the motivation factors that impact the success of the student allows for educators to further refine the curriculum to better prepare the students for post-graduation employment, producing more wellrounded graduates entering industry.

While the engineering curriculum provides students with the technical skills necessary to excel in industry, it lacks in teaching students professional skills. Senior capstone design courses teach students these skills such as project management, team work, and effective technical communication. For example, the requirements for capstone design typically include deliverables such as technical reports and presentations. This requires the student to properly convey their designs, data analysis and decision making parameters, improving their communication skills. Improving upon these technical skills produces higher quality, better prepared engineers entering industry.

12

Chapter 2 Motivating Studies

Mechanical engineering is the largest engineering discipline, accounting for 23.8% of the bachelor's degrees awarded in 2016.²⁹ 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%.^{30,31} 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.³²

Studies have suggested that demographics impact the motivation and performance of students. The participants of the quantitative study are requested to provide their demographic information for comparison. The demographics considered are gender, age, residency (domestic or international student), family income, and the highest degree obtained by the student's parents. The study also considers the student's GPA and whether or not the student had transferred into the private university to see if these factors impact the student's motivation.

13

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.³³ While the statistic reached a ten-year high in 2017, women still only accounted for 21.3% of all undergraduate engineering degrees.²⁹ Personal preference has been shown as the dominant reason women choose not to pursue STEM fields.³⁴ However, the lack of female students in STEM fields has been attributed to many different causes, including the gender stereotype that these fields are masculine fields. Other causes discussed by literature are: lack of female role models^{35–37}, lack of outreach to young girls³⁸, and the self-perception of the inability to succeed in these fields and low self-efficacy due to their gender³⁹.

While these issues can cause females to avoid entering the sciences altogether, there are also difficulties with the retention of female students upon entering a STEM field.⁴⁰ Some women do initially choose to pursue a STEM field, but choose not to persist. Women are 2.5 times more likely to leave a STEM field after entering university level study.^{41,42} Various research studies have shown that gender stereotypes are one of the driving factors behind attrition of women in STEM fields.⁴⁰

Motivation studies typically compare gender differences between two aspects of motivation: mastery goals and performance goals.^{43,44} 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.^{43,45} 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.⁴⁶

Research has suggested that adolescent females exhibit higher mastery goals, while males typically exhibit higher performance goals.^{45,46} This can be detrimental for males if their focus shifts too heavily toward maintaining their public image rather than learning the material.⁴⁵ Females focus more heavily on mastery of the material to increase their self-efficacy perception over time.^{45,47} However, females are also inherently exposed to a "stereotype threat". Stereotype threats are the feeling of judgment by peers based on societal stereotypes.^{41,48} This phenomena causes students to fear doing poorly because they feel they may be thereafter defined by this stereotype.⁴⁸ This may cause students to "disidentify" with the field that they feel uncomfortable with, which is typically STEM-related fields for females.^{41,48,49} 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.^{50–52} Shih, *et al.* also showed that self-identification and motivation factors can implicitly shift, which can improve or hinder overall performance.⁵³

Student Residency

Of all of the bachelor's degrees awarded in 2016, only 9.6% were awarded to international students²⁹; in 2017, this number rose to 10.1% of all of the engineering degrees awarded. Two driving factors behind student success are academic integration and social integration.^{54–56} 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. Depersonalized instruction has been revealed to cause students to disidentify with their field of study.⁵⁷ 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.⁵⁸ Abiding by new societal standards may be confusing or even offensive to the students depending on their previous residency and societal norm.⁵⁹ 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.^{59,60} 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.^{60,61} This is further exacerbated by the need to make formal presentations to their advisory committee in capstone design, causing anxiety for the students and pushing them away from a lead position.⁵⁹ Braxton, Sullivan, and Johnson found that academic integration and social integration are interrelated concepts.⁵⁴ 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 Florida Institute of Technology. This allows for an analysis of the differences between the domestic and international student populations. 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.^{60,62,63}

Family Socialization

In a similar regard as student residency, family socialization has been studied regarding its effects on postsecondary performance. Tinto hypothesized and studied the effect of the parent's education and socioeconomic status, as well as their expectation of the student, on the student's motivation and performance.⁵⁵ One study of Tinto's suggested that higher social status produced a higher aptitude on standardized tests,⁶⁴ whereas the opposite equally applies. This disparity stems from a student's early education and propagates through the student's academic tenure. A study by Gut, Reimann, and Grob confirmed prior research that children with low socioeconomic status and family expectations tend to perform poorly compared to students that have parents with higher status and a higher expectation of their competence.⁶⁵ At the university level, socioeconomic status impacts the student's performance on multiple levels. 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 entrance exams.⁶⁴

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.⁶⁶ 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.⁶⁷ 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.⁶⁴ 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.^{64,68}

Previous Student Performance

This work also accounts for the student's previous educational experience through the use of the student's cumulative GPA and whether or not the student had transferred into Florida Institute of Technology or had been here through the duration of their undergraduate tenure. While multiple studies have suggested that GPA is a flawed determination of the student's performance at the university level,^{69–71} others have shown that GPA tends to be consistent across semesters. ^{72,73} Students that have higher GPA's are generally expected to maintain a higher GPA, while students with a lower GPA tend to maintain a lower GPA. Therefore, the student's cumulative GPA is viewed with respect to their motivation levels and performance to see if a correlation exists.

With the rising cost of tuition at the university level, more students are taking courses at lower level colleges and transferring into university for their intermediate and higher level courses. Studies have also been conducted to determine the impact of transferring into university, versus attending university for the standard, four-year trajectory. A study by Dills and Hernandez-Julian found that students who transfer into university tend to perform poorly in their intermediate courses compared to students that enter university at the freshman level. While the difference was found to be small, it was statistically significant.⁷⁴ Another study by Sinha found that students that transfer into an undergraduate STEM program take longer to graduate than those that begin their program and finish their program at the same university.⁷⁵

Chapter 3 Student Motivational Factors

Academic success has been closely linked to the student's motivation.^{76,77} A study by Busato, *et al.* found that achievement motivation was one of the most influential factors to academic success, alongside intellectual ability.¹⁰ Moreover, intrinsic motivation factors have also been shown to greatly impact an individual's decision to pursue creativity and design.¹² Therefore, motivation is hypothesized to affect a student's 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 cite 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.

In this study, a modified version of the MSLQ survey is used 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 the MSLQ survey will result in significant differences in motivation between academic years, as well as differences between genders and other demographic qualities, 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 and highest degree obtained by parents. The student's previous academic history, including GPA and transfer status, is also considered against student motivation toward design.

Student Motivation

Pintrich identified the importance of motivation on academic performance.^{8,11,78} The two integral factors of motivation identified were ambition and learning.¹¹ The five motivational factors examined in this study are cognitive value, self-regulation, test/presentation anxiety, intrinsic value, and self-efficacy. Test/presentation anxiety, selfefficacy, and intrinsic value correspond to ambition, whereas cognitive value and selfregulation measure a student's learning. 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 because 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 sequence 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 who are not confident 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.⁷⁸ Self-efficacy is the student's confidence that he or she can achieve a goal. Self-efficacy is closely linked to expectancy,^{11,13} 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.⁷⁸ Seymour and Hewitt identified one of the root causes of attrition from STEM majors as the loss of self-efficacy.⁴² 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.^{49,79} 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.^{40,48,49,79}

Motivated Strategies for Learning Questionnaire (MSLQ)

The MSLQ was developed by researchers at the National Center for Research to Improve Postsecondary Teaching and Learning (NCRIPTAL), including Paul Pintrich, who is known as one of the leading figures in self-regulated learning and motivation. The MSLQ was formulated to determine the impact of student motivation on their performance. The MSLQ is a widely used tool in the academic community. The students are required to self-assess their motivation on a seven-point Likert scale, with a value of 1 corresponding to "not true to me at all" and a 7 corresponding to "very true to me". A value of 4 is accepted as neutral, and the other values are a gradient between the aforementioned digits.

A study by Pintrich and De Groot⁹ identified that self-efficacy, intrinsic value, cognitive value, and self-regulation predicted academic achievement, while test anxiety was negatively correlated to self-efficacy in seventh grade science and English students. The use of regression analysis showed that self-regulation, self-efficacy, and test anxiety predicted performance, however intrinsic value did not directly affect performance.⁸⁰ In another study by Pintrich, Roester, and De Groot, intrinsic value, self-efficacy, and test anxiety (used as motivation factors) were correlated to cognitive value and self-regulation (used as self-regulated learning).⁸⁰ Therefore, the five factors used in this study are cognitive value, self-regulation, self-efficacy, intrinsic value, and test/presentation anxiety. The MSLQ survey disseminated to the students is shown in Appendix A MSLQ Form and Survey Consent Form. It is important to note that this survey is the version given to the senior capstone design students. There are small changes made to the survey given to the freshman cornerstone design students. Recall, the study of the freshman students focuses on test anxiety whereas the study of the senior students focuses on presentation anxiety. Therefore, any instance of "presentation" or "present" in the MSLQ would be changed to "test" or "take an exam". For example, the question "I am so nervous during a presentation that I cannot remember facts I have learned" is altered in the freshman level survey to "I am so nervous during an exam that I cannot remember facts I

have learned". Any questions that are altered for the freshman level survey are shown in Table 1, below.

Question (Senior Capstone Design Survey)	Altered Question (Freshman Cornerstone Design Survey)
Compared with other students in <i>senior design</i> I expect to do well	Compared with other students in <i>Introduction</i> to <i>Mechanical Engineering</i> I expect to do well
I am so nervous during <i>a presentation</i> that I cannot remember facts I have learned	I am so nervous during <i>an exam</i> that I cannot remember facts I have learned
I often choose <i>research</i> topics I will learn something from even if they require more work	I often choose <i>paper</i> topics I will learn something from even if they require more work
I have an uneasy, upset feeling when I present	I have an uneasy, upset feeling when I <i>take a test</i>
I worry a great deal about presentations	I worry a great deal about taking tests
Understanding <i>the design process</i> is important to me	Understanding <i>the subject</i> is important to me
When I <i>present</i> I think about how poorly I am doing	When I <i>take a test</i> I think about how poorly I am doing
When I <i>prepare for a presentation</i> I put important ideas into my own words	When I <i>study for a test</i> I put important ideas into my own words
When I <i>prepare for a presentation</i> I try to remember as many facts as I can	When I <i>study for a test</i> I try to remember as many facts as I can
When <i>preparing for a presentation</i> , I copy my notes over to help me remember material	When <i>studying for a test</i> , I copy my notes over to help me remember material
I practice presentations even when I don't have to	I work on practice exercises and answer end of chapter questions even when I don't have to
When I <i>prepare for a presentation</i> , I practice saying the important facts over and over to myself	When I <i>study for a test</i> , I practice saying the important facts over and over to myself
I use what I have learned from <i>previous classes</i> to do prepare for project work	I use what I have learned from <i>old homework assignments and the textbook</i> to do new assignments
I outline the relevant topics to help me prepare for a presentation	I outline the relevant chapters in my book to help me study

Гаble 1 — Differences in	Questions between	Senior and Freshman	MSLQ
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Chapter 4 Research Methods

This research seeks to understand the relationship between student motivation and success in design courses. An overarching goal of this research is to develop a tool that could be disseminated early in the design course that identifies the students who are likely to underperform. This allows educators to develop an intervention plan for those specific students to ensure their success in the design course and their degree field.

Objective

The objective of the research is to understand the impact of student motivation on success in design courses. Student motivation will be measured quantitatively through the use of the MSLQ surveys, as well as qualitatively through the use of interviews. "Success" is measured using the student's performance in the respective course (measured by the final grade), as well as the student's persistence in mechanical engineering. The student's persistence is measured in a binary manner: whether the student did or did not finish their degree.

The study is conducted longitudinally. It views student data from three instances in time: the beginning of freshman cornerstone design, the beginning of senior fall capstone design, and the end of senior spring capstone design. This allows the unique opportunity to follow the same group of students through their two respective design courses, as well as examine the differences in motivation between the students that followed the standard, four-year trajectory and the students that did not.

Research Scope

This research examines the impact of motivation on performance in mechanical engineering design courses. The study examines a cohort of students, longitudinally. The first cohort includes data that was collected in the Fall of 2014, in freshman cornerstone design; data collection also occurred in the Fall 2016 and Spring 2017 semesters, during both semesters of senior capstone design. In a standard, four-year, undergraduate trajectory, the data would include the freshman and senior data for each of the two cohorts.

Research Questions & Hypotheses

The presented study specifically addresses three research questions, each of which are subdivided further, as shown in the table below.

Table 2 — Research Questions & Hypotheses

Ι	Question	Does a correlation exist between student motivation and success within students in engineering design curriculum?
	Hypothesis	There will be a correlation between student motivation and success in engineering design curriculum.
	Validation Approach	Student motivation is measured through the use of the MSLQ tool, in which students self-report their motivation on a 7-point Likert scale. The student motivation is analyzed using a linear regression analysis and paired T-test to determine if there are significant correlations in motivation and success.
	Question	Does a correlation exist between motivational factors and student success during each semester of senior capstone design (fall and spring)?
I.a.	Hypothesis	The short term success, or student performance, will be impacted by student motivation.
	Validation Approach	The short term student success will be measured through the use of the student's grade in their respective design courses. This grade will be compared to the student's motivation factors from the MSLQ.
	Question	Does a correlation exist between motivational factors and the change in student success over the course of the two semester senior capstone design course?
I.b.	Hypothesis	The student's motivation across a single year of academic study will show correlation to the change in student success, if change in success does exist.
	Validation Approach	The motivation of the students will be measured quantitatively through the use of the MSLQ survey, which will be compared to the student's change in grade over the two semesters of the course.
I.c.	Question	Can qualitative data collected via a team interview format provide insight into specific variables impacting student motivation and performance in senior capstone design?
	Hypothesis	Student feedback through the use of a qualitative interview will provide insight into variables impacting motivation and performance in senior capstone design.
	Validation Approach	Interview transcripts will be coded to identify factors that impact student motivation and performance.

П	Question	Does there exist a difference in student motivation throughout the student's college education?
	Hypothesis	Student motivation is dynamic and therefore will change based on external factors throughout the course of the student's education.
	Validation Approach	The MSLQ data will be examined using linear regression and t- tests to determine if there is a statistically significant change throughout the student's academic tenure.
	Question	Does a correlation exist between motivational factors and student success in freshman cornerstone design?
II.a	Hypothesis	There will exist a correlation between motivational factors and student success in freshman cornerstone design.
	Validation Approach	The student's motivation factors will be quantified using the MSLQ survey and compared to student success as defined by their final grade in the course.
	Question	Does a correlation exist between motivational factors and student success in senior capstone design?
II.b	Hypothesis	There will exist a correlation between motivation and student success in senior capstone design, based on preliminary results.
11.0	Validation Approach	The average motivation for each of the students will be determined using the senior capstone design MSLQ surveys, which will be considered with respect to the student's final grade in senior capstone design.
II.c	Question	Does a correlation exist between changes in motivational factors and student success in senior capstone design for the same cohort of students?
	Hypothesis	Given the extended period of time between freshman cornerstone design and senior capstone design, it may be difficult to attribute success to overall change in motivation.
	Validation Approach	The motivation factors from the freshman cornerstone design MSLQ will be examined with respect to the senior capstone design MSLQ to determine change in motivation across the curriculum. This will then be gauged with respect to student success, as defined by their grade in senior capstone design.

III	Question	Do initial and final motivation levels correlate to student success as defined by persistence?
	Hypothesis	Motivation is a dynamic, multifaceted phenomena and therefore it may be difficult to correlate motivation to persistence in a long term format.
	Validation Approach	The motivation factors from the MSLQ from freshman cornerstone design and senior capstone design will be correlated to the student's persistence, as defined by the completion of their degree.
	Question	Is there a statistically significant difference in the motivation of persisters compared to non-persisters?
III.a	Hypothesis	There are many factors that affect a student's retention or attrition in engineering, therefore it may be difficult to correlate motivation to persistence.
	Validation Approach	The motivation factors of the freshman cornerstone students that completed their degree will be compared to the motivation factors of students that did not complete a degree to see if significant differences exist.
III.b	Question	Does there exist a statistically significant difference in the motivation of students that followed a standard, four-year trajectory to those that did not?
	Hypothesis	There are many factors that affect a student's trajectory in undergraduate education, therefore it may be difficult to correlate motivation to persistence in this format.
	Validation Approach	The motivation factors of the freshman cornerstone students that completed their degree in four years will be compared to the motivation factors of students that took more time to complete their degree.
III.c	Question	Does there exist a statistically significant difference in motivation between the students that began their education at FIT to those who transferred into the university?
	Hypothesis	There are many factors that affect a student's transfer status; however, different curricula may have an impact on the student's motivation.
	Validation Approach	The motivation factors of transfer students will be compared to the motivation of students that started their education at FIT to see if statistically significant differences exist.

Research Approach

This section will outline some of the research approaches used in data analysis.

Cronbach's Alpha

To measure the validity of the quantitative survey instrument, Cronbach's alpha was calculated between each of the questions that relate to the five motivation factors studied. While the survey instrument is based off of Pintrich's Motivated Strategies for Learning Questionnaire (MSLQ), the questions were altered slightly to more closely examine students in design education. Therefore, a Cronbach alpha is calculated to ensure that the minor modifications made did not compromise the validity of the survey instrument. This is to ensure that the questions posed on the quantitative survey are closely related enough to justify their measurement of each of the motivation factors. Cronbach's alpha is expressed as a value between 0 and 1, where a value of 1 indicates an increased correlation.⁸¹ The scale used for this research is shown below ^{82,83}:

Rating	Numeric Value
Unacceptable	< 0.5
Poor	0.5-0.6
Questionable	0.6-0.7
Acceptable	0.7-0.8
Good	0.8-0.9
Excellent	>0.9

Table 3 — Cronbach's Alpha

The alpha values are also dependent on the number of variables measured, therefore for the purpose of this research, motivation factors with less questions addressing them may result in a lower Cronbach's alpha value. Alpha can also be used to determine if a test is unidimensional, but cannot be used to determine the degree of unidimensionality of the test.⁸⁴ The equation for Cronbach's alpha is shown below, in Equation 1.

Equation 1 — Cronbach's Alpha Calculation

$$\alpha = \frac{N * \bar{c}}{\bar{v} + (N-1) * \bar{c}}$$

In this equation, N is equal to the number of items, c-bar is the average inter-item covariance, and v-bar is equal to the average variance.

Cohen's Kappa

Cohen's Kappa is a method for examining qualitative, categorical data for two dichotomous variables. Kappa measures the degree of agreement between two independent judges, determining the location of *n* objects in *k* mutually exclusive categories.⁸⁵ Kappa is a preferred method of determining the level of agreement because it offers a chance-correction for the categorization of the variables. The chance-correction is employed by subtracting the expected value of agreement from the average values. Therefore, the mathematical equation for determining Kappa (κ) is given by:

Equation 2 — Cohen's Kappa

$$\kappa = \frac{\sum O_{ij} - \sum E_{ij}}{n - \sum E_{ij}}$$

where O_{ij} is the observed value, E_{ij} is the expected value, and n is the total number of variables. Cohen's Kappa is used to determine the interobserver reliability of the judges that are responsible for coding the qualitative exit interview data. The codes are extracted

on an individual basis between the two coders (judges) and organized into categories and subcategories based on the student responses. The resulting coding scheme was overseen by two master coders, who also serve to solve any discrepancies between the two coders.

Likert Scale

The Likert Scale was developed in 1932 to measure character, personality traits, and other qualitative information quantitatively.^{86,87} The original Likert scale was rated on a five-point scale: strongly approve (1), approve (2), undecided (3), disapprove (4), and strongly disapprove (5).⁸⁷ Since this time, many alternatives of the survey have been used; most Likert scales range from 3 points to 10 points. This research utilizes a seven-point Likert scale to improve the granularity of the responses. A value of 1 corresponding to "not true to me at all" and a 7 corresponding to "very true to me". A value of 4 is accepted as neutral, and the other values are a gradient between the aforementioned digits.

Based on the survey, the scale is classified as Likert-type or Likert scale. Likerttype questions do not combine responses into a composite scale. Likert scale questions are combined into a composite score. In this research, a Likert scale is used as each of the questions correspond to one of the five motivational factors. Typical data analysis for Likert scale items include mean for central tendency, standard deviations for variability, Pearson's r, t-test, ANOVA, or regression analyses.⁸⁶ This research uses t-tests and regressions analyses, as well as examines the applicability of probabilistic methods such as machine learning techniques.

T-tests

T-tests are parametric tests that use interval data to determine whether two or more independent samples represent two populations with differing mean values.⁸⁵ T-tests are based off of the t-distribution, which has an average of 50 and standard deviation of 10.⁸⁸ The t-distribution is a bell-shaped, symmetric, and continuous distribution where the t-value represents a standard deviation score. When the sample size being assessed approaches infinity, the t-distribution becomes a normal distribution. In order to perform a t-test, the test statistic must be calculated and compared to literature values for a critical t-value. The equation for the test statistic is shown in Equation 3:

Equation 3 — Test Statistic Calculation

$$t = \frac{\bar{x} - \mu}{s_{\bar{x}}}$$

Where x-bar is the mean, μ is the expected value from the null hypothesis, and s_{x-bar} is the estimated standard error of the unbiased standard deviation estimate. The calculation for the mean is shown below, in Equation 4,

Equation 4 — Mean Calculation

$$\bar{x} = \frac{\sum x}{n}$$

where the x values are the variables of interest, and n is the sample size of the population. The calculation for the unbiased standard deviation is shown in Equation 5 and the estimated standard error is shown in Equation 6.

Equation 5 — Standard Deviation Equation

$$\tilde{s} = \sqrt{\frac{\sum (x^2) - \frac{(\sum x)^2}{n}}{n-1}}$$

Equation 6 — Estimated Standard Error Equation

$$s_{\bar{x}} = \frac{\tilde{s}}{\sqrt{n}}$$

T-tests are employed in this research as we are seeking to determine whether average values of motivation factors differ significantly across the course of the design courses, from freshman cornerstone design to senior capstone design, and within senior capstone design.

Pearson's Correlation Coefficient

If two variables are correlated, it means that there exists a relationship between the variables. However, correlation does not address the cause-and-effect relationship between the variables. In other words, correlation cannot predict the direction of the relationship. Correlation comes in three forms: positive, negative, and zero.⁸⁸ Positive correlation between two variables indicate that both variables are either high or both variables are low. In other words, as the value for variable X increases, the value for variable Y would also increase. Alternately, negative correlation between two variables indicate that one variable X increases, variables indicate that one variable is high and the other is low; as variable X increases, variable Y decreases, or vice versa. Zero correlation indicates that one variable cannot be used to predict the value of the second variable. Correlation values vary between 1 and -1, where high positive correlation

results in a value of 1, high negative correlation results in a value of -1, and zero correlation results in a value of 0.

One statistical test for determining correlation between two variables is the Pearson correlation coefficient. The statistic for this test is r, where the equation for r is given by:

Equation 7 — Pearson's Correlation Coefficient⁸⁸

$$r = \frac{\sum(XY) - \bar{X}\bar{Y}}{SD_XSD_Y}$$

X-bar and Y-bar are the mean values for each of the two variables, and SD_X and SD_Y are the standard deviations of X and Y, respectively. The equation for the standard deviation of X is shown below, in Equation 8.

Equation 8 — Standard Deviation

$$SD_x = \sqrt{\frac{\sum(X^2)}{N} - \bar{X}^2}$$

The standard deviation of Y is computed similarly, switching the X's in the equation to Y's. The resulting r value can be evaluated compared to typical suggestions of correlation, shown in Table 4.

Table 4 — Pearson	Correlation	Coefficient Value	s ⁸⁸
$1 \text{ abic } \neq -1 \text{ carson}$	Contration	Councient value	10

Less than 0.2	Slight, almost negligible relationship
0.2-0.4	Low correlation, but small relationship
0.4-0.7	Moderate correlation, substantial relationship
0.7-0.9	High correlation, marked relationship
0.9-1.00	Very high correlation, very dependable relationship

In order to test the Pearson correlation coefficient for significance, we form a null hypothesis that there is no correlation. If the absolute value of the correlation coefficient is greater than the critical value, the null hypothesis is rejected and there is indeed correlation at that significance.

Linear Regression

Since correlation cannot guarantee causation, regression analyses are used as a method for predicting causation. In order to use a linear regression, the data must be linear, normal and homoscedastic. In any bivariate analysis, there will exist two different regression lines: the prediction of X onto Y and the prediction of Y onto X. There will also exist a residual error in the regression, where the discrepancy exists between the predicted values and the actual values. Provided that regression analysis can be used to predict future values as long as the data is significant, the regression analysis can identify useful trends in student motivation and performance to identify students that are more likely to underperform.

The goal of the research is to determine the impact of the five motivation factors and demographic information on success in design courses. Therefore, a covariate linear regression approach will be used. The criterion variable is the performance of the student, while the predictor variables are the other qualifying information. For a covariate linear regression, the line equation is given by:

Equation 9 — Linear Equation

$$Y_{predicted} = b_1 X_1 + b_2 X_2 + \dots + b_n X_n + a$$

where b_1 , b_2 ... b_n are the slope values of the corresponding X variable, and a is the intercept with the y-axis. The slope values are calculated as shown in Equation 10. It is important to note that this slope equation is for a line with X_1 and X_2 , for brevity.

Equation 10 — Slope Equation⁸⁸

$$b_1 = \frac{SD_Y}{SD_{X1}} \left(\frac{r_{y,1} - r_{y,2}r_{1,2}}{1 - r_{1,2}^2} \right)$$

Machine Learning

Machine learning is a subset of artificial intelligence (AI) that uses statistical techniques to improve at tasks due to previous execution of tasks.⁸⁹ In other words, machine learning is a method by which machines analyze past and current events to determine future events. The theoretical basis of machine learning lies in statistics because inferences are made from samples.⁹⁰ Machine learning models can be predictive to form assumptions about future events, descriptive to gain knowledge from the data, or a combination of both.⁹¹ Machine learning allows knowledge extraction, compression, and outlier detection. Knowledge extraction formulates a simple model that explains the data and provides explanation about the underlying process of the data. Data compression occurs when the raw data can be compressed based on the rules formulated by it, therefore requiring less memory. Machine learning produces greater data output than the amount of data input. Outlier detection identifies the anomalies in the data that may require attention.⁹⁰

There are two primary types of machine learning: supervised learning and unsupervised learning. Supervised learning attempts to map the inputs to the outputs knowing the correct values for the outputs. This typically results in a linear equation, or a nonlinear equation depending on the complexity of the relationship. Unsupervised learning occurs when the user only knows the input data, rather than also knowing the correct outputs.⁹⁰ The goal is to identify similarities in patterns in the data using density estimation or clustering metrics. Provided that the outputs are known in this context, this research will focus on the applicability of supervised machine learning for predicting the performance of the students due to their motivation factors.

Exploratory Factor Analytic Procedures

Principal component analysis and factor analysis are methods of reducing a data set of intercorrelated data into smaller subsets, called "components" or "factors".⁸⁵ Principal component analysis (PCA) is generally accepted as the better method for exploratory studies due to its simplicity. On the other hand, factor analysis (FA) is generally accepted as the more accurate description of relationships. To explain, there are three different types of variance in data⁸⁵:

- Common (shared) variance: a variance that is shared by two or more factors, which is assumed to be reliable
- (2) Specific (unique) variance: a variance that is specific to a single variable, which is assumed to be reliable
- (3) Error variance: variance that is out of the control of the researcher, which is assumed to be unreliable.

PCA accounts for all of the variance in a data set. FA only uses the common variance between the factors.

The goal of a factor analysis is to produce a simple structure, in which each of the variables only load highly onto a single factor. In order to achieve this, it may be necessary to apply a rotation. Orthogonal rotation redefines the linear combinations of the factors while maintaining independent factors. The most common form of orthogonal rotation is a varimax rotation as it simplifies the factors by maximizing the variance of the squared factor loading. There also exists an oblique rotation, which is applied if the factors are correlated with one another.⁸⁵ Pedhazur and Schmelkin suggest applying both types of rotation to a data set to ensure that an orthogonal rotation will be sufficient.⁹²

Internal Review Board Approval

This study involves using students as the experimental subjects. This requires approval through the Institutional Review Board (IRB) at Florida Institute of Technology. The paperwork ensures that the study is safe to all participants. The initial IRB documentation was approved in the Fall of 2013 to obtain the freshman cornerstone data the following year and in Fall 2016. An additional IRB form with necessary changes was approved in the Fall of 2018 to obtain the senior capstone data. A copy of the most recently submitted IRB form, and the approval is included in Appendix B IRB Application and Approval.

Chapter 5 Studies Completed

The study is performed using quantitative and qualitative input from a longitudinal cohort of students. The quantitative data is collected through the use of a modified version of Pintrich's MSLQ at three instances in time: the beginning of the fall semester of the student's freshman year, the beginning of the fall semester of the students' senior year and the end of the spring semester of the students' senior year. The qualitative data was collected in the spring semester of the students' senior year, after the conclusion of the senior capstone design course. The qualitative data serves to further explain the students' performances.

Quantitative and qualitative results are used to further explore the impact of student motivation on their performance in senior capstone design courses. The study also examines the student's motivation factors with regard to their demographic information. This includes the student's gender, age, residency (domestic or international), family income, and the highest degree attained by parents.

Study Subjects

The subjects in this study are all undergraduate students in mechanical engineering at Florida Institute of Technology. The students were enrolled in the freshman level cornerstone course Introduction to Mechanical Engineering during the fall of 2014 and then enrolled in the senior level capstone design course in the fall of 2017-spring of 2018. This would follow the typical, four-year trajectory to graduate with a bachelor's degree in mechanical engineering.

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 5. The freshman year students were 87.7% male and 12.3% female. Approximately 49% of the population are domestic students, while 51% are international students.

 Table 5 — Freshman Demographic Information

	Domestic	International	Total
Males	39	46	85
Females	9	3	12
Total	48	49	97

The data for capstone design was obtained in the fall and spring semesters of the students' senior year in their Mechanical Engineering Design 1 and Mechanical Engineering Design 2 courses. The data was collected during the second week of classes in the fall semester and during the last week of classes in the spring semester. When the data was collected for the fall semester, the students 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. When the data was collected for the spring semester, the students had already completed their projects and final presentations/reports. In the senior capstone design course, there are a total of 88 students. The demographic information for these students is provided in Table 6. 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.

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

 Table 6 — Senior Demographic Information

Quantitative Analysis

The quantitative data collection occurred at three instances in time: the first MSLQ survey was disseminated at the beginning of the fall 2014 semester, before the students had begun to work on their cornerstone design projects; the second MSLQ survey was disseminated at the beginning of the fall 2017 semester, before the students had begun to work on their senior capstone design projects; the final MSLQ survey was disseminated at the end of the spring 2018 semester, after the students had completed their senior design projects.

The MSLQ views five motivation factors: cognitive value, intrinsic value, selfregulation, self-efficacy, and test/presentation anxiety. Each of these five motivation factors are compared to the student's performance in the freshman cornerstone or senior capstone design course, which is measured through the use of the student grade for that semester. The student's demographic information is also taken into consideration to determine if trends exist within demographics or between demographics. The delta in the motivation factors is also compared to the change in the student's performance throughout the course sequence. This is again considered with respect to the student's demographic information to determine if trends exist within or across demographic groups.

The quantitative data was analyzed using two statistical methods – t-tests and linear regression – to compare subjects and correlate them to relevant variables. The linear regression seeks to determine if there is correlation between the hypothesized independent variables and the dependent variable (student performance). The analysis utilizes Akaike's Information Criterion (AIC) to find the best fit model since correlations may be multi-level.⁹³ Paired t-tests are also performed between the student's fall and spring MSLQ data for senior design, or the student's fall freshman cornerstone course and fall senior design course. Significance is considered to exist at an α <0.05, however, α <0.10 is maintained for discussion.

Qualitative Analysis

In order to gain more insight into the motivation factors, there was a qualitative interview at the end of the senior capstone design sequence. This qualitative study was performed at the end of spring semester 2018, as the students were finishing up their respective senior capstone design projects. Each of the nine student teams were requested to perform a group exit interview regarding their experience in senior capstone design. Some of the questions inquired to student groups were focused and targeted with regard to their motivation factors: "Were you motivated to do well in this course? If so, what were you motivated by?" Other questions were not as direct, but were intended to gain insight into the student's choice of senior design teams and future goals: "Do you intend on going to industry or continuing your education after graduation? Did senior capstone design play

any role in this?" and "Do you feel more confident in your ability as an engineer having completed this course?" This interview was implemented to address the secondary goal of the research to determine whether the student's qualitative responses could provide further insight into the variables affecting motivation and performance in design courses.

Each of the qualitative interviews by the nine senior capstone design teams were transcribed, and the research team individually extracted the codes from the transcriptions. The result was 69 different codes, each of which were recurring topics from the exit interviews of the students. A few examples of these codes include "teamwork", "potential job opportunity", "skills", and "grades". A coding tree is presented in Appendix C Coding Tree. This coding scheme is used to correlate recurring topics to motivation factors and performance in the course. The Cohen's Kappa coefficient⁸⁵ to measure the agreement of the author's codes was calculated to be $\kappa = 0.99$. Any value of over $\kappa = 0.75$ is generally accepted to be excellent⁹⁴, while some have arbitrarily suggested that a value of $\kappa = 0.81$ -1 as perfect agreement for the model⁹⁵.

Chapter 6 Motivation in Senior Capstone Design

Recall the five motivational factors examined were the student's cognitive value, self-regulation, anxiety (in the form of presentation anxiety), intrinsic value, and selfefficacy. The student's demographic information was also used as a parameter of interest, including their gender, residency, parent's highest educational attainment, family income, and previous education experience.

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 evaluated on a continuous grading scale, from 0-100. The basic scale is shown in Table 7, below. This is also referenced with the scale that is used by Florida Institute of Technology to determine the student's grade point averages. Therefore, a grade of 90-100 signifies an A.

Student Grade	Numeric Value	GPA
А	100-90	4
В	89-80	3
С	79-70	2
D	69-60	1
F	59-0	0

For the senior capstone design analysis, in order to draw direct comparison, only the students who completed both of the senior capstone design MSLQ surveys (fall and

spring), as well as the qualitative exit interview were considered. This reduces the student cohort size to 80 students. The demographic information for the students is shown in Table 8. In the normalized cohort of students, 87.5% are male and 12.5% are female. The international population of students is larger than the domestic population: approximately 59% and 41%, respectively.

Table 8 — Senior Comparison Study Subjects

	Domestic	International	Total
Males	27	43	70
Females	6	4	10
Total	33	47	80

Motivation in Senior Capstone Design 1 (Fall 2017)

A linear regression was performed for each of the students in the cohort to determine which of the five motivation factors of interest impacted their performance (measured using student's final grade in the course). The students' fall grades were found to be impacted by their intrinsic value and their cognitive value, with significances of p=0.00509 and p=0.03318, respectively. Figure 1 shows the correlation between the student's self-reported intrinsic value and performance for the Fall 2017 senior capstone design course.



Figure 1 — Correlation of Senior Fall Performance to Intrinsic Value and Cognitive Value

It is shown that students with higher intrinsic value earned higher grades in the course. Recall, the MSLQ surveys were disseminated at the beginning of the senior capstone course, before the students had begun working on their projects. Therefore, students entering with a higher self-confidence in their ability and perception of the importance of senior capstone design performed better than students without. The student's cognitive value had an opposite effect on their grades; students with increased ability to recognize the necessary sequence of tasks required to complete a goal tended to earn lower grades. Also, it is important to note that the student's cognitive values were not impacted by their demographic information, including gender or residency, when entering into senior capstone design. However, the student's intrinsic values were impacted by their residency, with a significance of p = 0.077. While this is greater than the desired p < 0.05, it is maintained for discussion purposes.

Motivation in Senior Capstone Design 2 (Spring 2018)

An AIC analysis was also performed using the spring senior capstone design final grades and student's self-reported motivation factors. Again, intrinsic value and cognitive value were determined to be the primary determinations for the student's performance. The impact of cognitive value was found to be further exacerbated by the student's intrinsic value. Figure 2 shows the correlation between student performance (measured using course grades) and cognitive value.



 Intercept
 85.013
 17.067
 4.981
 3.78e-06

 Cognitive Value
 -5.975
 2.877
 -2.077
 0.0412

 Intrinsic
 6.274
 3.294
 1.905
 0.0606

 Residual standard error:
 16.81
 F-statistic:
 2.727

 Model p-value:
 0.07173
 2.07173
 2.07173

Figure 2 — Correlation of Senior Spring Performance to Intrinsic and Cognitive Value

While a p-value < 0.05 was preferred, a p-value < 0.1 is maintained for discussion. As shown in Figure 2, the student's cognitive value was significant to p-value < 0.05(p=0.0412); however, the model p-value was less than 0.1 at a p-value of = 0.07173. Similar to the fall semester, students with higher cognitive value earned a lower grade in the course.

Interestingly, the research identified that the student's performance was significantly related to the student's residency for the spring semester of senior capstone design. This is shown in Figure 3 below. The domestic students performed significantly higher (p=0.005) in the spring semester than the international students.



Figure 3 — Comparison and Correlation of Mean Grades to Residency

Changes in Motivation and Performance over the Course of Senior Capstone Design

The linear regression model for the change in motivation and performance between the fall and the spring semesters showed that the change in the students' grades were impacted by the change in their intrinsic value. Figure 4 shows the relationship between the change in grade from the fall to spring semesters and the change in intrinsic value. The model p-value = 0.0336. The trend line shows students that performed poorly in the spring semester of senior capstone design saw a decrease in intrinsic value. However, it is peculiar to note that only students that exhibited an increase in intrinsic value were the students that had a minimal change in their grade between the fall and spring semesters; most students experienced a decrease in intrinsic value, even if their grades increased significantly between the fall and the spring semesters.



Figure 4 — Correlation between Changes in Course Grade to Changes in Intrinsic Value between Fall and Spring Semesters

Model p-value: 0.0336

Qualitative Analysis

To supplement the quantitative study results, an exit interview was performed with each of the senior capstone design teams. The students were asked a total of 19 questions, in an open-floor, interview type format. The students were instructed to be as specific as possible in their answers. These were subsequently coded using qualitative transcripts to identify recurring factors contributing to the students' motivations and performances. The students were also provided with contact information for the principal investigator, in the event that they were uncomfortable disclosing information in front of the other students or wanted to expand upon their answers outside of the meeting time.

There were 69 unique codes that were realized through the interviews. These codes were generalized into the following themes: selection, process, and results. The "selection" theme primarily focused on the entrance into senior capstone design; this included reasoning behind specific project selections and current and future goals for the students. The "process" theme explored the period of time during senior capstone design. This included the student's challenges and motivation for persistence, as well as the senior design experience as a whole. Finally, the "results" theme generally looked at the outcome of senior capstone design, including any skills and reflections by the students. The three main themes, as well as their sub-themes are shown below in Table 9. This also shows the occurrence of each of the sub-themes. The count is the total number of times that factor was mentioned during the exit interviews with the student teams.

Table 9 — Qualitative Factors

Theme	Sub-Theme	Count
	Personal	87
	Previous Experience	21
Selection	Current Goals	19
	Future Goals	24
	Challenges	15
	People	127
Process	Challenges/Motivations	85
	Project Requirements	6
	Future	15
Results	Skills	37
	Reflections	152

The qualitative analysis determined that personal goals had a major impact on student's project selection. While future goals played a role, it was personal ambitions that were referenced when detailing why one selected their respective project. When referencing the process of the design course, students often referenced the personnel involved, specifically their teammates. The team element of the design experience seemed to have a significant impact on the students' perception of the design process. When discussing the results of the project, students reflected on their decisions and activities often. The reflection is a positive sign as reflection is often a necessary component of learning. Students often reflected on what they would do differently or decisions they made that were later found to be instrumental to their progress.

Discussion of Results

The senior capstone design student's fall performance was found to be correlated to their cognitive and intrinsic values (p < 0.05). Likewise, their spring performance was found to be correlated to their cognitive value which was further exacerbated by their intrinsic value; however, the model lacked significance (p = 0.0717); the model is maintained for discussion at a p < 0.1. The student's intrinsic value is their confidence in completing the task at hand and their recognition of its significance for their learning. The students that recognized the significance of the course tended to outperform the students that do not. The student's cognitive value is their ability to recognize the sequence of tasks necessary to complete a goal. Students exhibiting higher cognitive value levels received lower scores in both semesters of senior capstone design.

An interesting finding was that the student's fall performance was not affected by their demographic information; however, their spring performance was impacted by their residency, with significance. The domestic students received higher grades in the spring than their international counterparts. Studies have identified that social integration can be problematic for international students;^{54,96} this includes language barriers that may exist, making it difficult for them to understand colloquial English in informal environments. ^{59,60} This is challenging for the students, especially in a group environment such as senior capstone design. Likewise, studies have shown that the international students have a difficult time succeeding in courses requiring the students to give formal presentations, which is true in senior capstone design.^{20,54,97} During the qualitative data collection, international students often cited the nontraditional mode of course presentations instead of traditional course learning modes (sitting in class or laboratory). Further, international students expressed concern that their limited English-speaking ability may adversely affect their team.

It was also found that the student's intrinsic value decreased overall from the beginning of the fall semester of senior capstone design to the end of the spring semester of

senior capstone design. A t-test comparison was performed to observe the change in intrinsic value between the fall and the spring semester of capstone design. As detailed in Table 10, the intrinsic value decreased significantly from approximately 6.19 to 5.55 to a p-value < 0.0001.

Intrinsic Value	Fall	Spring
Mean	6.1889	5.5472
Standard Deviation	0.4108	0.4559
Pearson Correlation	0.5309	
t Stat	8.9935	
p-value	1.0e-13	
t Critical	1.9905	

Table 10 — Intrinsic Value Paired T-Test Results

In addressing the research question I.a- *Does a correlation exist between motivational factors and student success during each semester of senior capstone design (fall and spring)*?- a positive correlation exists in each of the semesters, where an increased intrinsic value indicates increased performance. This correlation is significant in the fall semester, but insignificant during the spring. A negative correlation exists between the student's cognitive values, where an increased cognitive value results in a lower performance for both fall and spring semesters.

The student's change in motivation levels was observed with respect to the change in their final grades between the fall and spring semesters of senior capstone design. It is found that the change in the student's intrinsic value was correlated to the change in their grade (p < 0.07127). However, as discussed, the students' intrinsic values decreased with significance between the fall and spring semesters of senior capstone design.

In addressing research question I.b - *Does a correlation exist between motivational factors and the change in student success over the course of the two semester senior capstone design course?* - the change in intrinsic value between the two semesters is correlated to the change in final grade of the cohort. While this correlation was found to be significant, many of the students experienced a decrease in intrinsic value. The only students that experienced an increase in intrinsic value did not see a change in grade between the fall and the spring semesters.

The qualitative exit interviews identified 69 unique codes that were segmented into a tree with the three overarching themes being:

- Selection prior to entering senior capstone design,
- Process during the process of senior design, and
- Results goals and factors at the completion of senior design capstone design.

Selection saw the students most concerned with their personal goals, having an occurrence of 87; process was heavily dependent on the people sub-themes with an occurrence of 127; results were influenced by reflections with an occurrence of 152.

Selection- The personal goals identified by the students included the subcategories of:

- Desirability of project
- Interest in project
- Competition project
- Industry project

- Confidence
- Desire to design
- Desire to help

Entering into senior capstone design, the students were primarily concerned with their choice of project. This included their desire and interest in their project choice, including their choice of participating on a competition or industry sponsored project. The students also identified their desire to help and design. These results are consistent with the quantitative results from the prior semester, indicating the student's performance was impacted by their intrinsic motivation. The students recognized the importance of the task at hand and were confident in their abilities to complete their project. The students that indicated that project choice was important generally spoke of the prospective impact of their project. For example, many of the industry teams indicated that their project choice was based off of the possibility of getting a job with that company post-graduation. The students were cognizant that their performance in the course and on their project could successfully result in a career with that company.

Process- The *people* subcategory included a multitude of subdivisions that were grouped into:

- University resources
- External resources
- Team

The university resources included personnel within the department (the professor and the graduate student assistants), the machine shop instructors, and our student design center's assistants. External resources were identified by the industry sponsored teams as their appointed industry representative. The team category specifically looked at the members of the team and their skillsets, team dynamics, and communication.

Results- The reflections subcategory of results included the subcategories of:

- Good experience/consistent project choice
- Learning
- Application of previous courses
- Graduate school motivation
- Success on other teams
- Change of project choice
- Desire for prerequisites

At the conclusion of senior design, many students indicated that they had a positive experience and had felt that they had learned many skills throughout the course of senior design. Moreover, students indicated they would choose the same project again if they were to do it again. Students recognized the need to apply their previous coursework during to ensure successful project completion. Some students indicated their desire to attend graduate school due to their experience in senior design. Also, some students indicated that they were confident that they could have been successful on any other senior design team having acquired the necessary skills. On the other hand, some students indicated that they felt that they would have been *more* successful on a different senior design team and would change their project choice if they were given the chance to start senior design over again. A few students indicated that there should be additional introductory and prerequisite courses required before entering into senior capstone design because they felt that they were ill-prepared for the professional standards needed to succeed. It is hypothesized that responses such as these could be an indication as to why the student's intrinsic value decreased over the two semester sequence. The students entered senior capstone design confident in their ability to complete their design challenge and perform at an industry level. The experience of senior design allowed for the students to reflect on their strengths and weaknesses, and identify possible areas of improvement in their skills; this includes technical skills and competencies as well as professional skills and competencies.

In addressing research question I.c - *Can qualitative data collected via a team interview format provide insight into specific variables impacting student motivation and performance in senior capstone design?* - the qualitative student interviews provide insight into the quantitative results, such as the decrease in intrinsic value between the two semesters of senior capstone design.

Chapter 7 Longitudinal Changes in Motivation and Performance

For the longitudinal component of the study (fall freshman to fall senior), 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 portion only considered common students between the cornerstone and capstone course that took both MSLQ surveys entering into their respective design course. The demographic information for the students of interest in the study is provided in Table 11. 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 11 — Longitudinal Comparison Study Subjects

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

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 student's motivation entering the course was found to have little impact on the outcome of the course. However, the student's gender was found to impact their performance in the course. While significance is found is p < 0.05, p-values of
0.1 or lower are maintained for discussion. The student's gender was found to impact their grade to a significance of p = 0.1, as shown below.



Figure 5 — Comparison and Correlation of Mean Grades to Gender

There is overlap in the standard deviation of the grades between the two genders. Recall that the sample size for females in the normalized cohort is only three. Therefore, it is difficult to conclude that gender is a driving factor behind performance in freshman cornerstone design.

To further examine the student's performance with respect to the five motivation factors, the data was grouped into 5 different levels. Each of the grades were correlated to a numeric value as shown in Table 12 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.

Student Grade	Numeric Value Assigned
А	4
В	3
С	2
D	1
F	0

Table 12 — Numeric Grade Values

The AIC analysis using the chunked data determined that anxiety and residency had the greatest correlation to student performance in the cornerstone course (model pvalue = 0.08769). The student's final grades were found to be negatively impacted by the student's anxiety levels. Figure 6 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 erro F-statistic: 2.65 Model p-value: 0.0876	or: 0.7801 59			

Figure 6 — 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.

Freshman Motivation on Senior Performance

Motivation is a dynamic, multidimensional phenomena that impacts performance over time. However, for the longitudinal cohort of 32 students, the students' freshman cornerstone motivation was compared to the students' senior capstone design grades. It was examined to determine whether students exhibiting higher motivation at the beginning of their first semester of collegiate study carry that through their four years of study.

It was found that the student's intrinsic value and self-efficacy impacted their performance during their first semester of senior capstone design, with significance.



Figure 7 — Cornerstone Motivation vs. Senior Performance

Students exhibiting higher intrinsic value and higher self-efficacy during their first semester of collegiate study tended to perform better in their senior capstone design course. Freshman intrinsic value is found to impact senior performance to p=0.0205, while freshman self-efficacy is found to impact senior performance to p=0.0245. The model p-value is found to be 0.055; while this is higher than the desired p < 0.05, it is maintained for discussion.

Longitudinal Changes in Motivation and Performance (Fall 2014 – Fall 2017)

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 is most correlated to changes in performance. Consider Figure 8, which illustrates the grades of domestic and international students in the cornerstone and capstone courses.



Figure 8 — 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 counterparts. As seen in Figure 9, the domestic population made greater strides in improving their grades between cornerstone and capstone, compared to international students; however, this correlation was realized to a p = 0.1 and therefore only maintained for discussion.



Residency5.8653.5891.6340.112Residual standard error: 10.13F-statistic: 2.67Model p-value: 0.112

Figure 9 — Residency vs. Change in Grade

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 13, the average anxiety of the senior class only decreased slightly from that of the freshman class.

Table 13 — 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). Therefore, the students still have similar anxiety during their senior year, but do not allow it to dictate their performance in senior capstone design. 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 14. The average intrinsic value increased over 0.65 points, with a significance value of p < 0.01.

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	

Table 14 — Intrinsic Value Paired T-Test Results

Discussion of Results

Since the use of continuous grading (0-100 scale) did not show any correlation between motivation and performance in the cornerstone design class, the students were clustered into an A-F rating system to further explore whether motivation could be used to remotely predict performance during the students' freshman studies. Through this method, the freshman design students' 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.⁹⁸ 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.⁶⁰ While most of the international students surveyed indicated that 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.⁶⁰ In addressing research question II.a – *Does a correlation exist between motivational factors and student success in Freshman Cornerstone Design?* - it is found that a negative correlation does exist between student success and anxiety in freshman engineering. This relationship is further exacerbated when considering international students.

The students' freshman level motivation factors were also examined with respect to their senior capstone design (Fall 2017) grade. The goal was to determine whether students entering university exhibiting certain motivation characteristics would perform better in their higher level engineering curriculum. It was found that the students' performance in their senior capstone design was correlated to their freshman level intrinsic value and self-efficacy, with significance. This means that students entering university with a higher self-confidence and comprehension of reasoning for completing a task performed better at the end of their degree program. In addressing research question II.b – *Does a correlation exist between motivational factors and student success in Senior Capstone Design*? - a positive correlation exists between both intrinsic motivation and student success, as well as self-efficacy and student success. However, correlation does not necessarily imply causation, especially when viewing data from two points in time that are four years apart.

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, in addressing research question II.c – *Does a correlation exist between changes in motivational factors and student success in senior capstone design for the same cohort of students?* - it is identified that no motivational factor changes correlate to changes in student success between both courses. However, in retrospect, this is a

multidimensional problem, and 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 the engineering curriculum. Thus, changes in motivation could almost be expected, but do not necessarily have to correlate to the changes experienced in course performance.

During cornerstone design, the students' grades are correlated to the students' anxiety levels, whereas in capstone design the students' grades are highly correlated to their intrinsic values, cognitive 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.^{78,99} To explore this, Table 15 shows the students' increase in cognitive value was significant to p < 0.05.

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	

Table 15 — Cognitive Value Paired T-Test Results

Pintrich found that students with higher anxiety levels exhibited lower cognitive values.⁷⁸ 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.^{13,78}

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.

Chapter 8 Impact of Motivation on Persistence in Mechanical Engineering

The third research question addresses the impact of motivation on student persistence in mechanical engineering at Florida Institute of Technology. This will focus on different cohort groups of students, as outlined in the subsequent sections.

Recall, the total cohort for the freshman cornerstone design course, shown in Table 16. The freshman year students were 87.7% male and 12.3% female. Approximately 49% of the population are domestic students, while 51% are international students.

Table 16 — Freshman Cornerstone Demographics

	Domestic	International	Total
Males	39	46	85
Females	9	3	12
Total	48	49	97

Impact of Motivation on Persistence

The impact of student motivation was measured with respect to the student's persistence. Here, we define persistence as the completion of their degree in mechanical engineering at Florida Institute of Technology. It is also important to note that the students will be broken into two groups: "persisters" and "non-persisters". The persisters consist of students that completed the freshman cornerstone survey in Fall 2014 and have since (at any point in time) graduated with a bachelor's degree in mechanical engineering from

Florida Institute of Technology. The non-persisters are the students that completed the freshman cornerstone survey in Fall 2014 and thereafter did not graduate with a degree in mechanical engineering. Some of the non-persisters have been identified to have changed their major or transferred to another department, transferred to another university, or exercised full attrition from university. The demographics for the persisters and the non-persisters are shown in Table 17 and Table 18, respectively.

Table 17 — "Persisters" Demographics

	Domestic	International	Total
Males	21	27	48
Females	4	0	4
Total	25	27	52

Table 18 — "Non-persisters" Demographics

	Domestic	International	Total
Males	18	19	37
Females	5	3	8
Total	23	22	45

A linear regression was performed to determine the impact of motivation on success of each of these groups. "Success" is determined by the student's final grade in freshman cornerstone design.

The AIC analysis found that the persisters' grades were correlated to their selfregulation motivation factor to a p < 0.05. However, it is interesting to note that the students with higher levels of self-reported self-regulation generally received lower final grades in the course. This is shown in Figure 10 below.



Figure 10 — Persisters' Self-Regulation versus Final Grade

Recall, self-regulation is described as the student's ability to structure themselves to complete a goal. Therefore, students that perceived themselves as poor at organizing themselves to complete a goal actually performed better throughout the course than those that believed that they were capable.

In examining the group of non-persisters, their final course grades were highly correlated to their anxiety levels, to a p < 0.005. Students exhibiting higher levels of

anxiety in their introductory course received lower final grades. This is shown in Figure 11 below.



Figure 11 — Non-Persisters' Anxiety versus Final Grade

Recall, the MSLQ survey is disseminated just a few weeks into the freshman level course, before the students have submitted many assignments or taken any exams. However, these students still exhibit a large amount of test anxiety in the course that has a negative impact on their grades. This could be due to the uncertainty of expectations of collegiate coursework and examination.

Impact of Motivation on Trajectory

This research also seeks to explore whether student motivation has any impact on their trajectory through university. While Introduction to Mechanical Engineering is intended to be a first semester, freshman level course, some students do not necessarily follow the standard trajectory through university. This can be the case for students that transfer into the university from other schools or students that are unable to take the course their first semester. Students that completed their freshman level cornerstone surveys in the Fall of 2014 would (on a standard trajectory) complete their senior level capstone surveys in the Fall of 2017 & Spring of 2018. However, of the respondents to the cornerstone surveys and 2018-2019 academic years.

Table 19 outlines the demographic information for the students that completed the capstone surveys during the 2015-2016 academic year.

	Domestic	International	Total
Males	2	0	2
Females	0	0	0
Total	2	0	2

Table 19 — Fall 2015 Demographic Information

The Fall 2015 students both transferred into Florida Institute of Technology and effectively took the freshman level Introduction to Mechanical Engineering at the beginning of their junior year. There is no correlation found between motivation factors and success in the course. This is due to the fact that the sample size is too small to compute (two students).

Table 20 shows the demographic information for the students that took their senior capstone surveys during the 2016-2017 academic year.

	Domestic	International	Total
Males	0	9	9
Females	0	0	0
Total	0	9	9

Table 20 — Fall 2016 Demographic Information

All nine students were international males. The students' final grades in their cornerstone design course were found to be correlated to their anxiety levels, with a significance of p < 0.05. This is shown in Figure 12.



Figure 12 — Fall 2016 Anxiety vs. Grades

Students in this group that exhibited higher levels of anxiety received lower final grades in their cornerstone design class. The sample size is still very low (only 9 students total).

Table 21 shows the demographic information for the students that completed their capstone course during the 2017-2018 academic year. This group has the largest sample size, as these students would have followed a standard, four-year trajectory.

	Domestic	International	Total
Males	18	17	35
Females	3	0	3
Total	21	17	38

Table 21 — Fall 2017 Demographic Information

Of the students in this group, 92% were males (51% domestic and 49% international) and 8% were domestic females. The AIC analysis for the standard trajectory students showed no correlation between their motivation factors and their final grades in their cornerstone course.

Table 22 shows the demographic information for the students that completed their capstone design surveys during the 2018-2019 academic year. These students would have followed a five-year trajectory to graduation.

	Domestic	International	Total
Males	1	1	2
Females	1	0	1
Total	2	1	3

Table 22 — Fall 2018 Demographic Information

This group consisted of three students: one domestic male, one international male, and one domestic female. Again, this sample size is too small to find correlation between motivation factors and student performance in cornerstone design.

Due to many of the sample sizes being too small to correlate, the data is parsed into larger groups consisting of the "standard trajectory" students and the "non-standard trajectory" students. Therefore, the students that took their Freshman level Introduction to Mechanical Engineering course in the Fall of 2014 and their senior level capstone course in the Fall of 2017-Spring of 2018 (four total years to graduation) versus the rest of the freshman sample.

Recall, the motivation factors did not correlate to student performance for the standard trajectory students. However, it was found that the non-standard trajectory students' success was correlated to their anxiety, which was further exacerbated by their self-regulation. The model p-value < 0.005.



	Coefficients	Standard Error	t Stat	P-value
Intercept	130.02	14.327	9.075	1.93e-06
Anxiety	-5.261	1.393	-3.776	0.0031
Self-Regulation	-5.822	3.087	-1.886	0.0860
Residual standard error: 7.817 F-statistic: 12.14 Model p-value: 0.0016				

Figure 13 — Non-Standard Trajectory Results

The students' anxiety shows correlation to a p-value < 0.005 while the students' selfregulation p < 0.1 is maintained for discussion. Students exhibiting lower levels of anxiety at the beginning of the cornerstone course earned higher final grades at course conclusion.

Motivation in Transfer Students

In examining the data regarding the motivation of students that transferred into the university versus those that did not, the student's senior MSLQ data was used. This is done because transfer students tend to perform poorly in their higher level courses compared to students that enter university at the freshman level⁷⁴ or take longer to graduate than those that begin their program and finish their program at the same university.⁷⁵

In order to draw direct comparison, only the students who completed both MSLQ the senior capstone design MSLQ surveys (fall and spring), as well as the qualitative exit interview were considered. The demographic information for the transfer students is shown in Table 23. The non-transfer students account for 72.5% of the senior class, while 27.5% of students transferred into Florida Institute of Technology. Of the transfer students, 81.8% were males and 18.2% were females. The non-transfer students were 89.7% males and 10.3% females.

Table 23 — Senior Comparison Study Subjects

	Transfer	Non-transfer	Total
Males	18	52	70
Females	4	6	10
Total	22	58	80

Three different sets of data are examined for the transfer and non-transfer students: the students' senior fall MSLQ data, the students' senior spring MSLQ data, and the delta between senior fall and senior spring.

Transfer Student Performance

The transfer students' motivation was examined with respect to their senior fall MSLQ data and it was found that transfer students' motivation was correlated to their intrinsic value, with significance. As shown in Figure 14, students that exhibited higher levels of intrinsic value at the beginning of their fall semester earned higher grades throughout the fall semester than students with lower levels of intrinsic value.



Figure 14 — Transfer Student Fall Performance

While the transfer students' intrinsic value drove their success during the fall semester of capstone design, there was no correlation discovered between the transfer students' motivation factors and performance in the spring semester of capstone design. There was also no correlation to report between the delta for the motivation factors and the delta for student performance across the yearlong capstone course.

Non-Transfer Student Performance

The non-transfer students' performance was also examined with respect to their motivation for the fall, spring, and delta values in capstone design. Figure 15 shows the correlation between the non-transfer students' fall performance and self-efficacy.



Figure 15 — Non-Transfer Fall Performance

The students' performance is found to be correlated to their self-efficacy to p < 0.05, which is further exacerbated by their cognitive value to p < 0.1. The model p = 0.0642, which is greater than the target p < 0.05, but maintained for discussion as p < 0.1. The non-transfer students' spring performance was also found to be correlated to their motivation in the course. The students' grades were now directly correlated to their cognitive value, which is further exacerbated by their intrinsic value, as shown in Figure 16.



Figure 16 — Non-Transfer Spring Performance

The students' cognitive value is correlated to a p < 0.05, with a model p-value < 0.1, as maintained for discussion. Interestingly, students with higher cognitive values earned lower grades in the course. It is also important to note that the students' delta values for motivation and performance were found to have no correlation.

Discussion of Results

The results show that the persister's performance in their freshman design course was determined by their self-regulation and the non-persister's performance was determined by their anxiety, both with significance. It is peculiar to note that the persisters with higher self-regulation values received lower grades in the course. This could be due to the inherent uncertainty and creativity required to complete the design process. While design has formalized methods with structured approaches, there exists some uncertainty in design. Design does not have a single "right answer", which could be a challenge to students that thrive off of structure and process. For the non-persisters, anxiety dictated their performance in the course. Higher levels of anxiety resulted in lower final grades.

In order to further explore motivation differences between the persisters and the non-persisters, t-tests were conducted to determine whether there existed a statistically significant difference in motivation between the two groups. None of the motivation factors showed a statistically significant difference between the two groups; however, there was a statistically significant difference in the students' grades, as shown below.

Grade	Persisters	Non-Persisters
Mean	79.96	72.68
Standard Deviation	10.24	10.60
t Stat	3.437	
p-value	0.0008	
t Critical	1.985	

Table 24 — Grade T-Test Results

The average grade in Introduction to Mechanical Engineering for the students that persisted through their undergraduate education in mechanical engineering was a 79.96, whereas the students that did not persist had an average grade of 72.68. The difference was statistically significant, to a p < 0.001.

Again, self-regulation and anxiety were shown to be the two determining factors for the persisters and non-persisters, respectively. However, there was not a statistically significant difference in the anxiety of the persisters and the non-persisters (p = 0.25) or the self-regulation of the persisters and the non-persisters (p = 0.43). The other three factors were also tested for comprehensiveness and were found to not have a statistically significant difference between the two groups.

In addressing research question III.a – *Is there a statistically significant difference in the motivation of persisters compared to non-persisters?* - each groups' performance was found to be dictated by a different motivation factor; however, there was not a statistically significant difference in motivation between the two groups.

Examining the student's motivation and performance based on their trajectory proved to be difficult due to some sample sizes and differences in student experience between groups. The 2015-2016 and 2018-2019 academic year seniors had too small of a sample size, with two and three students, respectively. The 2016-2017 academic year group's performance was found to be impacted by their anxiety. Students exhibiting higher levels of anxiety earned lower final grades in their cornerstone design course. While the sample size was small (nine students), the results were found to be significant. Peculiarly, the 2017-2018 academic year students – the students that followed a standard, four-year trajectory for the undergraduate curriculum – were found to have no correlation between their motivation and performance in their freshman cornerstone design course. Table 25 shows the average motivation values for each of the academic years.

Academic Year	Cohort Size	Cognitive Value	Self- Regulation	Anxiety	Intrinsic Value	Self- Efficacy
2015-2016	2	4.792	4.722	2.250	5.444	5.778
2016-2017	9	5.315	4.827	5.111	5.704	5.642
2017-2018	38	4.950	4.453	3.601	5.613	5.159
2018-2019	3	5.222	4.519	5.833	6.259	4.296
Non-persisters	45	5.102	4.625	4.289	5.378	4.874

Table 25 — Average Motivation Values by Academic Year

While the samples sizes may be too small to find significance through statistical testing, it is interesting to note some of the differences in means between the cohorts of students. The cognitive values, self-regulation values, and intrinsic values are relatively consistent across all student groups in their freshman cornerstone design course (no greater than 1 point). However, the anxiety and self-efficacy values differ by academic year. The students that are furthest along in their degree (2015-2016 academic year) exhibit the lowest anxiety levels. This could be due to the fact that the students that are furthest along in their degree load to completion of their degree and therefore are less anxious about the remainder of their studies. The students that followed the standard, four-year trajectory exhibit the second lowest anxiety levels (2017-2018 academic year). This could be due to the fact that the students are just beginning their academic journey, but are confident in their abilities. Conversely, on average, student's self-efficacy levels are higher when the students are closer to graduation, with the students completing a five year trajectory exhibiting the lowest self-efficacy.

When the data was parsed into two larger groups (standard trajectory versus nonstandard trajectory) to mitigate the effects of insufficient sample size, it was found that the students that followed a non-standard trajectory had a correlation between their performance and anxiety levels, which was further exacerbated by their self-regulation; the students that followed a standard trajectory did not show correlation between motivation and performance. Therefore, t-tests were performed to examine whether there were significant differences between the standard and non-standard trajectory students' average motivation factors. The student's anxiety differed, with significance, between the two groups; this is shown below in Table 26.

Table 26 — Standard vs. Non-Standard Anxiety T-test

Anxiety	Standard	Non-Standard
Mean	3.601	4.857
Standard Deviation	1.736	1.572
t Stat	2.452	
p-value	0.018	
t Critical	2.008	

The students that followed a standard trajectory had significantly lower anxiety levels than the students that followed a non-standard trajectory to a p < 0.05.

In addressing research question III.b – *Does there exist a statistically significant difference in the motivation of students that followed a standard, four-year trajectory to those that did not?* - the students that followed a non-standard trajectory were found to be influenced by their anxiety levels. The students that followed a standard, four-year trajectory were also found to have significantly lower levels of anxiety compared to the students that followed non-standard trajectories.

In examining the differences between transfer and non-transfer students during their senior year, the data was examined for their fall, spring, and delta information across the two semesters of senior capstone design. The transfer students' fall performance was impacted by their intrinsic value, to a model p < 0.05. However, t-tests revealed that there was not a significant difference between the transfer students' and non-transfer students' intrinsic values. This indicates that the transfer students' performance was dictated by their perception of the importance of the task at hand, while the non-transfer students' performance was note a significant that the transfer students may perceive senior capstone design as a more important factor to their education than the non-transfer students. None of the motivation factors were found to correlate to the transfer students spring or delta performance values at a level of significance.

The non-transfer students' fall performance was found to be driven by their selfefficacy, which was further exacerbated by their cognitive value. While the model p-value is higher than desired to prove significance, p = 0.064 < 0.1 was maintained for discussion. There were no significant differences found in the self-efficacy or the cognitive values of between the transfer and non-transfer students for the fall semester. However, the impact of self-efficacy on the non-transfer students' performance indicates that their performance in the fall semester is driven by their internal self-confidence or expectations of performance. Therefore, the non-transfer students may feel more prepared through their three years of curriculum to take on the challenge of senior capstone design than the transfer students. In the spring semester, the non-transfer students' performance was found to be linked to their cognitive value, which is further exacerbated by their intrinsic value. Again, the model pvalue = 0.076 < 0.1 is maintained for discussion purposes. In the spring semester, the nontransfer students were driven by their ability to recognize the necessary tasks, as well as the sequence of tasks, to complete a successful project. This could be due to the fact that the students have already overcome the uncertainty in their design and now have a plan to prototype, test, and build their final product. However, higher cognitive values resulted in lower final grades in the course. This highlights the difference between cognitive value and self-regulation. Cognitive value is the student's ability to recognize the tasks required, as well as the necessary sequence of tasks, to complete a goal. Even if students are able to recognize the tasks, it does not necessarily mean that they are able to structure themselves to complete the tasks; the ability to structure oneself to successfully complete the tasks at hand is measured through the use of the student's self-regulation.

In addressing research question III.c – *Does there exist a statistically significant difference in motivation between the students that began their education at FIT to those who transferred into the university?* - the performance of the two cohorts of students are shown to be driven by different motivation factors in each of the semesters; however, the difference in motivation between the transfer and non-transfer students is not found to be statistically significant.

Chapter 9 Discussion and Conclusions

This longitudinal study seeks to examine the effect of student motivation on success in mechanical engineering design curriculum. The design curriculum of interest at Florida Institute of Technology includes the students' freshman-level (cornerstone) Introduction to Mechanical Engineering course and their yearlong, senior-level (capstone) design sequence consisting of Mechanical Engineering Design 1 and Mechanical Engineering Design 2. Student motivation is examined with respect to the students' performance to determine if any motivation factors correlate to the students' performance in the design course. The motivation factors observed in the study are cognitive value, selfregulation, anxiety, intrinsic value, and self-efficacy. Quantitative data collection, through the use of the Motivated Strategies for Learning Questionnaire (MSLQ) occurred at three points in time: the beginning of the student's freshman cornerstone design course, the beginning of the student's fall semester of senior capstone design, and the end of the student's spring semester of senior design. Qualitative data was also collected through the use of capstone team-based exit interviews at the conclusion of the senior design course.

The study addresses three overarching research questions that are each subdivided into three sub-questions. Table 27 outlines the conclusions of each of the nine research sub-questions.

Table 27 — Research Question Results

Ι	Question	Does a correlation exist between student motivation and success within students in engineering design curriculum?
	Hypothesis	There will be a correlation between student motivation and success in engineering design curriculum.
	Validation Approach	Student motivation is measured through the use of the MSLQ tool, in which students self-report their motivation on a 7-point Likert scale. The student motivation is analyzed using linear regression analysis and paired T-test to determine if there are significant correlations in motivation and success. Qualitative exit interviews are used to gain further insight into student experiences in capstone design.
I.a.	Question	Does a correlation exist between motivational factors and student success during each semester of senior capstone design (fall and spring)?
	Hypothesis	The short term success, or student performance, will be impacted by student motivation.
	Research Outcome	A positive correlation exists in the fall semester, where an increased intrinsic value indicates increased performance. A negative correlation exists in the spring semester, where an increased cognitive value indicates decreased performance.
I.b.	Question	Does a correlation exist between motivational factors and the change in student success over the course of the two semester senior capstone design course?
	Hypothesis	The student's motivation across a single year of academic study will show correlation to the change in student success, if change in success does exist.
	Research Outcome	The change in intrinsic value between the two semesters is correlated to the change in final grade of the cohort. Interestingly, most students experienced a decrease in intrinsic value, regardless of their final grade.
I.c.	Question	Can qualitative data collected via a team interview format provide insight into specific variables impacting student motivation and performance in senior capstone design?
	Hypothesis	Student feedback through the use of a qualitative interview will provide insight into variables impacting motivation and performance in senior capstone design.
	Research Outcome	The qualitative student interviews provide insight into the quantitative results, such as the decrease in intrinsic value between the two semesters of senior capstone design.

П	Question	Does there exist a difference in student motivation throughout the student's college education?
	Hypothesis	Student motivation is dynamic and therefore will change based on external factors throughout the course of the student's education.
	Validation Approach	The MSLQ data will be examined using linear regression and t- tests to determine if there is a statistically significant change throughout the student's academic tenure.
II.a	Question	Does a correlation exist between motivational factors and student success in freshman cornerstone design?
	Hypothesis	There will exist a correlation between motivational factors and student success in freshman cornerstone design.
	Research Outcome	It is found that a negative correlation does exist between student success and anxiety in freshman cornerstone design. This relationship is further exacerbated when considering international students.
II.b	Question	Does a correlation exist between motivational factors and student success in senior capstone design?
	Hypothesis	There will exist a correlation between motivation and student success in senior capstone design, based on preliminary results.
	Research Outcome	A positive correlation exists between both intrinsic motivation and student success, as well as self-efficacy and student success. However, correlation does not necessarily imply causation, especially when viewing data from two points in time that are four years apart.
II.c	Question	Does a correlation exist between changes in motivational factors and student success in senior capstone design for the same cohort of students?
	Hypothesis	Given the extended period of time between freshman cornerstone design and senior capstone design, it may be difficult to attribute success to overall change in motivation.
	Research Outcome	It is identified that no motivational factor changes correlate to changes in student success between both courses. However, in retrospect, this is a multidimensional problem, and 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.
	Question	Do initial and final motivation levels correlate to student success as defined by persistence?
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III	Hypothesis	Motivation is a dynamic, multifaceted phenomena, and therefore it may be difficult to correlate motivation to persistence in a long term format.
	Validation Approach	The motivation factors from the MSLQ from freshman cornerstone design and senior capstone design will be correlated to the student's persistence, as defined by the completion of their degree.
	Question	Is there a statistically significant difference in the motivation of persisters compared to non-persisters?
III.a	Hypothesis	There are many factors that affect a student's retention or attrition in engineering, therefore it may be difficult to correlate motivation to persistence.
	Research Outcome	Each groups' performance was found to be dictated by a different motivation factor, however there was not a statistically significant difference in motivation between the two groups.
	Question	Does there exist a statistically significant difference in the motivation of students that followed a standard, four-year trajectory to those that did not?
III.b	Hypothesis	There are many factors that affect a student's trajectory in undergraduate education, therefore it may be difficult to correlate motivation to persistence in this format.
inic	Research Outcome	The students that followed a non-standard trajectory were found to be influenced by their anxiety levels. The students that followed a standard, four-year trajectory were also found to have significantly lower levels of anxiety compared to the students that followed non-standard trajectories.
	Question	Does there exist a statistically significant difference in motivation between the students that began their education at FIT to those who transferred into the university?
III.c	Hypothesis	There are many factors that affect a student's transfer status; however, different curricula may have an impact on the student's motivation.
	Research Outcome	The performance of the two cohorts of students are shown to be driven by different motivation factors in each of the semesters; however, the difference in motivation between the transfer and non-transfer students is not found to be statistically significant through t-tests.

Recommendations

Based on the research findings presented in this work, it is shown that student motivation has an impact on student performance and persistence in mechanical engineering design courses. Therefore, the use of the MSLQ survey is recommended to identify important student motivation factors in each year of mechanical engineering design curriculum. This will not only allow for identification of relevant motivation factors for that particular cohort of students, but also allow for an intervention plan to be created to target specific motivation factors that may be lacking. The intervention plan can include changes made within the design curriculum to improve student performance.

In examining which of the motivation factors impact students at different points in time throughout the curriculum, we were able to identify areas of improvement in our current senior capstone design sequence and implement an intervention plan to improve student motivation and performance in senior design capstone.¹⁰⁰ As an example, a student's intrinsic value was found to correlate to their performance in senior capstone design; however, it was discovered that a student's intrinsic value decreased significantly across the two semester senior capstone course. The student's intrinsic value is their internal self-confidence and perception of reasoning for participating in a certain task or course. Therefore, in our intervention plan, we specifically targeted the student's intrinsic value through meetings and practice sessions with the graduate student assistants. This allowed the students to present their work in a more comfortable, less formal setting, allowing for confidence to be built and corrections to be made without the worry of negative impacts on their grade. The positive reinforcement provided by the graduate

student assistants through this small change was found to increase the student's intrinsic value and decrease their anxiety throughout the course of senior capstone design.

Limitations

Given the multifaceted nature of this research, limitations exist for each of the three research questions posed. The first research question focuses on student motivation throughout the course of a yearlong senior capstone design. One of the primary limitations was the fact that data was only collected at two instances in time: before the students began working on their senior capstone design projects and when the course had concluded and students were finished with their capstone design projects. While this was intentionally designed to prevent survey fatigue, it may be insightful to include an additional survey between the two semesters of the course to gather data from the students while they are fully engaged in their projects. It also may be beneficial to collect qualitative data from the students at the start of their senior capstone design experience. The qualitative data was only collected once the students had completed their projects, requiring them to answer some of the questions in a reflective manner. An additional limitation of the study was the ability to gather qualitative data from each of the students in the senior capstone design course. Given the size of the senior capstone design class, it was not possible to schedule and perform comprehensive individual student interviews. Therefore, the qualitative exit interviews were administered on a by-team basis. This resulted in nine, thirty minute interviews with each of the senior design teams. This provides a snapshot of the variables impacting student motivation and performance. However, some of the students did not get the chance to participate at all, or did not feel comfortable disclosing this information in

front of their colleagues. To mitigate these effects, the participants were provided with the list of interview questions and contact information to send responses; this was intended to allow for the students to expand upon some of their answers or disclose information in a private setting. While some students did take advantage of this opportunity, it is not certain that all possible factors were extracted for review.

The second research question focuses on the student's freshman cornerstone design experience and the longitudinal components for the students that followed a standard trajectory through their undergraduate experience. One of the primary limitations 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. Additionally, the results for this questions were limited by 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 38 of them followed the standard trajectory of four-year completion. Of these, only 32 completed both surveys for longitudinal comparisons. Nine of the students completed senior design in the previous school year, two completed senior design in two years prior to the normal trajectory. Three students finished their degree in a total of five years. The remaining 45 students have either

transferred to a different major or are no longer enrolled at the university. This is summarized in Table 28.

Senior Capstone Attendance	Number of Students
Standard Projection	38
One year ahead	9
Two years ahead	2
One year behind	3
No longer enrolled	45

Table 28 — Freshman Student Statistics

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.

With respect to the third research question – further examining student persistence, trajectory, and transfer status – the limitations are similar to those noted above. Unfortunately, qualitative entrance interviews were not performed with the freshman cornerstone design students at the beginning of their cornerstone design experience. Therefore, we do not have a mixed methods approach to examine the student's freshman experience. Additionally, it is difficult to determine where the non-persisters went or when they decided to no longer pursue mechanical engineering at Florida Institute of Technology. Studies have shown that typically one-half of student attrition in engineering occurs during their first year at university. Many others leave during their subsequent years, stating the development of disinterest or refocus of interest on other endeavors.¹⁰¹ Provided that the data is collected at the beginning of the student's freshman year, we cannot determine the reasons for their attrition.

Future Research Direction

In motivation research for design engineering students, there are many avenues to be explored. The nature of the future direction of this longitudinal research falls primarily into one of two categories: repeatability or refinement. The repeatability of this research would focus on further validation of trends through the use of additional longitudinal studies. Increasing the sample size to multiple classes of students would allow for improved granularity regarding recurring factors at the freshman/senior levels. Additionally, future work 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 (or multiple instances every year) 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.

The refinement of the research can be subdivided into refinement of quantitative analysis and the refinement of qualitative analysis. Historically, the MSLQ has been proven to identify the level of student motivation in the postsecondary curriculum. The questions posed can be further developed to focus more succinctly on the engineering curriculum, specifically design courses for this purpose. Questions can be developed and then validated through the use of exploratory factor analytical procedures to be employed in design courses. Refinement of the qualitative analysis could improve the data gathered and warrant a more effective analysis. While the survey was proven to be robust and provided effective feedback with respect to the changes in motivation factors, the initial feedback from the student can be used to tailor the data to efficiently gauge student motivation. For example, one recurring topic in the qualitative interview was the importance of the graduate student assistants (GSAs) for the team. The GSAs would provide extrinsic motivation.¹⁰² Therefore, the graduate student would be a factor affecting the student's intrinsic value. This code of "GSAs" would consequently correspond to intrinsic value within the context of the survey.

The overarching goal of this research is to refine the information to develop a survey that could be implemented throughout the curriculum to determine which students exhibit a high likelihood of failure or attrition. This would afford educators the ability to implement an intervention plan for these students, increasing their opportunities for short and long term success in their degree field and producing more high quality engineers entering the workforce.

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Appendix A MSLQ Form and Survey Consent Form

	Motivated Strategies for Learning Questionnaire
Name	Team:
1.	Florida Tech ID Number (e.g. 900XXXXXX):
2.	 What is your academic standing? O Freshman O Sophomore O Junior O Senior
3.	Were you a transfer student? O Yes O No a. If yes, what semester did you transfer to FIT?
4.	 Are you a domestic or international student? O Domestic O International a. If international, state your country: b. If domestic, what is the zip code of your permanent home address (back home)?
5.	What is the highest degree earned by your parents?
6.	What is your gender? O Female O Male O Do not want to report
7.	What is your age group? O 17-20 O 21-24 O 25 and above O Do not want to report

8. What is your GPA? O < 2.0 O 2.0-2.5 O 2.5-3.0 O 3.0-3.5 O 3.5+ O Do not want to report

9. With which racial group(s) do you identify? (Mark ALL that apply)

O African-American or Black

- O Caucasian/White
- O South Asian (e.g. Indian, Pakistani, Bangladeshi, etc.)
- O Other AsianO Other:
- O East Asian (e.g. Chinese, Korean, Japanese, etc.)
- O Native Hawaiian or Pacific IslanderO American Indian or Alaskan Native
- O Do not want to report

Rate the following items based on your behavior in this class. Your rating should be on a 7-point scale where 1= not at all true of me to 7=very true of me.

Question	Not True						Very True
I prefer work that is challenging so I can learn new things.	1	2	3	4	5	6	7
Compared with other students in senior design I expect to do well	1	2	3	4	5	6	7
I am so nervous during a presentation that I cannot remember facts I have learned	1	2	3	4	5	6	7
It is important for me to learn what is being taught in this class	1	2	3	4	5	6	7
I like what I am learning	1	2	3	4	5	6	7
I'm certain I can understand the ideas taught in this course	1	2	3	4	5	6	7
I think I will be able to use what I learn in this class in my life	1	2	3	4	5	6	7
I expect to do very well in this class	1	2	3	4	5	6	7
Compared with others in this class, I think I'm a good student	1	2	3	4	5	6	7
I often choose research topics I will learn something from even if they require more work	1	2	3	4	5	6	7
I am sure I can do an excellent job on the problems and tasks assigned	1	2	3	4	5	6	7
I have an uneasy, upset feeling when I present	1	2	3	4	5	6	7
I think I will receive a good grade in this class	1	2	3	4	5	6	7
Even when I do poorly, I try to learn from my mistakes	1	2	3	4	5	6	7
I think that what I am learning in this class is useful for me to know	1	2	3	4	5	6	7
My study skills are excellent compared with others in this class	1	2	3	4	5	6	7

I think that what we are learning in this class is interesting	1	2	3	4	5	6	7
Compared with other students in this class I think I know a great deal about the subject	1	2	3	4	5	6	7
I know that I will be able to learn the material for this class	1	2	3	4	5	6	7
I worry a great deal about presentations	1	2	3	4	5	6	7
Understanding the design process is important to me	1	2	3	4	5	6	7
When I present I think about how poorly I am doing	1	2	3	4	5	6	7
When I do homework, I try to remember what the teacher said in class so I can answer the questions correctly	1	2	3	4	5	6	7
I ask myself questions to make sure I know the material I have been studying	1	2	3	4	5	6	7
It is hard for me to decide what the main ideas are in what I read	1	2	3	4	5	6	7
When work is hard I either give up or study only the easy parts	1	2	3	4	5	6	7
When I prepare for a presentation I put important ideas into my own words	1	2	3	4	5	6	7
I always try to understand what the teacher is saying even if it doesn't make sense.	1	2	3	4	5	6	7
When I prepare for a presentation I try to remember as many facts as I can	1	2	3	4	5	6	7
When preparing for a presentation, I copy my notes over to help me remember material	1	2	3	4	5	6	7
I practice presentations even when I don't have to	1	2	3	4	5	6	7
Even when study materials are dull and uninteresting, I keep working until I finish	1	2	3	4	5	6	7
When I prepare for a presentation, I practice saying the important facts over and over to myself	1	2	3	4	5	6	7
Before I begin studying I think about the things I will need to do to learn	1	2	3	4	5	6	7
I use what I have learned from previous classes to do prepare for project work	1	2	3	4	5	6	7

I often find that I have been reading for class but don't know what it is all about.	1	2	3	4	5	6	7
I find that when the teacher is talking I think of other things and don't really listen to what is being said	1	2	3	4	5	6	7
When I am studying a topic, I try to make everything fit together	1	2	3	4	5	6	7
When I'm reading I stop once in a while and go over what I have read	1	2	3	4	5	6	7
When I read materials for this class, I say the words over and over to myself to help me remember	1	2	3	4	5	6	7
I outline the relevant topics to help me prepare for a presentation	1	2	3	4	5	6	7
I work hard to get a good grade even when I don't like a class	1	2	3	4	5	6	7
When reading I try to connect the things I am reading about with what I already know.	1	2	3	4	5	6	7

SURVEY CONSENT FORM

Please read this document thoroughly and sign at the bottom.

We are seeking your participation in a research project involving the study of student motivation and time allocation in undergraduate academic tenure.

If you agree to participate, you will fill out a hand written Motivated Strategies for Learning Questionnaire (MSLQ). The time required to complete this activity is about 10-15 minutes. Your participation will not subject you to any physical pain or risk.

Your survey responses will be known to, at most, three people: two researchers and Dr. Beshoy Morkos, the director of this study. We assure you that any reports about this research will contain only data of an anonymous or statistical nature. Your identity will be kept confidential to the extent provided by law. Your information will be coded with an identification number, instead of any personally identifying information. The list connecting your name to this number will be kept in a locked file in Dr. Beshoy Morkos' office. When the study is completed and the data has been analyzed, the list will be destroyed. Your name will not be used in any report.

Any questions you have regarding this research may be directed to Elisabeth Kames or Dr. Beshoy Morkos at the emails provided below:

Elisabeth Kames: ekames2011@my.fit.edu

Dr. Beshoy Morkos: bmorkos@fit.edu

This study was approved by Florida Institute of Technology's IRB. Information involving the conduct and review of research involving human may be obtained from the Institutional Review Board of the Florida Institute of Technology at 321-768-8000 ext. 8104.

Your signature below indicates that you agree to participate in this research and that:

- 1. You have read and understand the information provided above.
- 2. You understand that participation is voluntary and that refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled; and
- 3. You understand that you are free to discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled.

Participant Name

I have explained and defined in detail the research procedures in which the subject has consented to participate.

Participant Signature

Date

Interviewer Name

Appendix B IRB Application and Approval

Florida Institute of Technology

RESEARCH INVOLVING HUMAN PARTICIPANTS EXEMPT APPLICATION

This form shall be used if there is **minimal risk** to human subjects; one of the categories on the next page applies to the research. If there is more than minimal risk associated with the research (none of the conditions apply) or if the research utilizes a special population (children, prisoners, institutionalized individuals, etc.), please use the expedited/full application form found on the IRB website.

You should consult the university's document "Principles, Policy, and Applicability for Research Involving Human Subjects" and instructions on the IRB Committee website prior to completion of this form. http://www.fit.edu/research/committees/irb

Submit via email to FIT_IRB@fit.edu.

IRB Contact Information: Dr. Lisa Steelman IRB Chairperson Isteelma@fit.edu or FIT_IRB@fit.edu 321-674-7316

INVESTIGATOR INFORMATION

Title of Project Engineering Motivation and Time Allocation Study

Date of Submission 9/26/2017

Expected Project Start Date 10/16/2017

16/2017 Expected Project Duration 3 academic years

Email bmorkos@fit.edu

Principal Investigator Beshoy Morkos

Title Assistant Professor

Academic Unit Mechanical and Aerospace Engineering

Phone 321-674-8780

List all co-investigator(s). Please include name, title, academic unit/affiliation and email.

Elisabeth Kames, Graduate Student Assistant, Department of Mechanical and Aerospace Engineering, ekames2011@my.fit.edu

> Florida Institute of Technology-Institutional Review Board 150 West University Boulevard, Melbourne, FL 32901-0975+321-674-7316+isaellma@flit.edu

PV-592-816 Fage 1 of 4 Florida Institute of Technology

RESEARCH INVOLVING HUMAN PARTICIPANTS EXEMPT APPLICATION

ANSWER THE FOLLOWING QUESTIONS AS THOROUGHLY AS POSSIBLE.

1. List the objectives of the proposed project.

The purpose of this study is to measure what motivates individuals working toward an undergraduate degree in mechanical engineering. The objective of the study is to determine if correlation exists between student motivation and the students success in their courses, including senior capstone design. This longitudinal study will also allow the researchers to observe the changes in motivation of a student throughout various years of undergraduate tenure. Ultimately, the goal is to determine what incentives best motivate students to perform well.

 Describe the research project design/methodology. Discuss how you will conduct your study, and what measurement instruments you are using. Attach all research materials to this application. Please describe your study in enough detail so the IRB can identify what you are doing and why.

The students will be given a Motivated Strategies for Learning Questionnaire (MSLQ) to determine the student motivation (attached to this form). The survey will be administered to the undergraduate students once a year, with the exception of the senior students. The senior mechanical engineering students will take the survey twice a year (beginning of the fall and end of the spring semesters) to measure the change in motivation due to their capstone design project experiences. The survey is intended to take about 20 minutes to complete.

 Describe the characteristics of the participant population, including number, age, sex and recruitment strategy (attach actual recruitment email text, recruitment fliers, etc).

The participants will be undergraduate mechanical engineering students. The students will be verbally recruited to take part in the survey through their courses, with the principal investigator reaching out to faculty to disseminate the survey to their classes. The age and sex of the participants vary throughout the sample population.

4. Describe any potential risks to the participants (physical, psychological, social, legal, etc.) and assess their likelihood and seriousness. Describe steps that will be taken to mitigate each risk.

There exists no potential risk in this study.

 Describe the procedures you will use to maintain the confidentiality and privacy of your research participants and project data. If video or audio recordings will be made, you must review the video/audio recording policy found on the IRB website and address precautions you will take in this section.

Students will be assigned an alphanumeric identification tag which is coded to contain their demographic information, if they choose to include it on their survey. (i.e. FYDF1C could indicate a freshman, transfer student that is a domestic female student between the ages of 17-20, and caucasian) The identification tag will not possess the student's name or any part of their full name. The document will be viewed only by the PI and destroyed after the study.

6. Describe your plan for informed consent (attach proposed form).

A consent form (attached) will be given to the students before administering the survey. Students may opt to not participate in this study at no consequence.

2. Objects the importance of the knowledge that will result from your study (benefits to the field and to society) and what benefits will accrue to your participants (if any). Include information about participant compensation if appropriate.

The importance of this study lies in understanding the impact of motivation in mechanical engineering undergraduates. This knowledge may assist faculty in understanding how to motivate subsequent classes of students and deploying the most successful motivation methods to ensure academic success. Students may learn from their reflection on the courses during the final survey senior year. Taking the survey may allow students to reflect on their motivation and make adjustments to improve themselves.

8. Explain how your proposed study meets criteria for exemption from Institutional Review Board review (as outlined on page 2 of this form). This research meets the criteria for exemption as it meets exemption 1 by performing the research in an education setting (classroom) and involving normal education practices. The educational practice will be used to compare the effectiveness of various forms of motivation (grade, pride, instructor satisfaction, instructor feedback).

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Florida Institute of Technology

RESEARCH INVOLVING HUMAN PARTICIPANTS EXEMPT APPLICATION

CATEGORIES OF EXEMPT RESEARCH Research must choose one:

Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as: a. research on regular and special education instruction strategies, or

b. research on the effectiveness of or the comparison among instruction techniques, curricula or classroom management methods.

- Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior unless:
 - a, the subjects can be identified, directly or through identifiers linked to the subjects and
 - b. any disclosure of subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability or reputation.
 - Note: This exemption does not apply to survey procedures or interviews involving minors.
- Research involving the use of educational tests, survey or interview procedures, or observation of public behavior if: a. the subjects are elected or appointed public officials or candidates for public office, or b. the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
- Research involving the collection or study of existing data, documents, records or specimens if these sources are publicly available or if the information is recorded by the investigator in such a manner that subjects cannot be identified, indirectly or through identifiers linked to the subjects.
- Research and demonstration projects that are conducted by or subject to the approval of department or agency heads and that are designed to study, evaluate or otherwise examine:
 - a. public benefit or service programs,
 - b. procedures for obtaining benefits or services under those programs,
 - c. possible changes in or alternatives to those programs or procedures, or
 - d. possible changes in methods or levels of payment for benefits or services under those programs.
- Taste and food quality evaluation and consumer acceptance studies if:
- a. wholesome foods without additives are consumed, or
 - b. food is consumed that contains food ingredients found to be safe by the Food and Drug Administration or approved by the Environmental Protection Agency or the Food Safety and Inspection Service of the U.S. Department of Agriculture.

RESEARCH FUNDING

If any part of this study will be funded by an external funding source, you must note the funding source and award/solicitation number below:

Office of Naval Research Solicitation #: N00014-16-R-FO03

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PV-502-016 Rage 2 of 4 Florida Institute of Technology

RESEARCH INVOLVING HUMAN PARTICIPANTS EXEMPT APPLICATION

ANSWER THE FOLLOWING QUESTIONS AS THOROUGHLY AS POSSIBLE.

1. List the objectives of the proposed project.

The purpose of this study is to measure what motivates individuals working toward an undergraduate degree in mechanical engineering. The objective of the study is to determine if correlation exists between student motivation and the students success in their courses, including senior capstone design. This longitudinal study will also allow the researchers to observe the changes in motivation of a student various years of undergraduate tenure. Ultimately, the goal is to determine what incentives best motivate students to perform well.

 Describe the research project design/methodology. Discuss how you will conduct your study, and what measurement instruments you are using. Attach all research materials to this application. Please describe your study in enough detail so the IRB can identify what you are doing and why.

The students will be given a Motivated Strategies for Learning Questionnaire (MSLQ) to determine the student motivation (attached to this form). The survey will be administered to the undergraduate students once a year, with the exception of the senior students. The senior mechanical engineering students will take the survey twice a year (beginning of the fall and end of the spring semesters) to measure the change in motivation due to their capstone design project experiences. The survey is intended to take about 20 minutes to complete.

 Describe the characteristics of the participant population, including number, age, sex and recruitment strategy (attach actual recruitment email text, recruitment fliers, etc).

The participants will be undergraduate mechanical engineering students. The students will be verbally recruited to take part in the survey through their courses, with the principal investigator reaching out to faculty to disseminate the survey to their classes. The age and sex of the participants vary throughout the sample population.

4. Describe any potential risks to the participants (physical, psychological, social, legal, etc.) and assess their likelihood and seriousness. Describe steps that will be taken to mitigate each risk.

There exists no potential risk in this study.

 Describe the procedures you will use to maintain the confidentiality and privacy of your research participants and project data. If video or audio recordings will be made, you must review the video/audio recording policy found on the IRB website and address precautions you will take in this section.

Students will be assigned an alphanumeric identification tag which is coded to contain their demographic information, if they choose to include it on their survey. (i.e. FYDF1C could indicate a freshman, transfer student that is a domestic female student between the ages of 17-20, and caucasian) The identification tag will not possess the student's name or any part of their full name. The document will be viewed only by the PI and destroyed after the study.

6. Describe your plan for informed consent (attach proposed form).

A consent form (attached) will be given to the students before administering the survey. Students may opt to not participate in this study at no consequence.

2. Objects the importance of the knowledge that will result from your study (benefits to the field and to society) and what benefits will accrue to your participants (if any). Include information about participant compensation if appropriate.

The importance of this study lies in understanding the impact of motivation in mechanical engineering undergraduates. This knowledge may assist faculty in understanding how to motivate subsequent classes of students and deploying the most successful motivation methods to ensure academic success. Students may learn from their reflection on the courses during the final survey senior year. Taking the survey may allow students to reflect on their motivation and make adjustments to improve themselves.

8. Explain how your proposed study meets criteria for exemption from Institutional Review Board review (as outlined on page 2 of this form). This research meets the criteria for exemption as it meets exemption 1 by performing the research in an education setting (classroom) and involving normal education practices. The educational practice will be used to compare the effectiveness of various forms of motivation (grade, pride, instructor satisfaction, instructor feedback).

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SIGNATURE ASSURANCES

I understand Florida Institute of Technology's policy concerning research involving human participants and I agree:

- 1. to accept responsibility for the scientific and ethical conduct of this research study.
- to obtain prior approval from the institutional Review Board before amending or altering the research protocol or implementing changes in the approved consent form.
- to immediately report to the IRE any serious adverse reactions and/or unanticipated effects on subjects which may occur as a result of this study.
- 4. to complete, on request by the IRB, a Continuation Review Form if the study exceeds its estimated duration.

Pl Signature	Date	
PI Signature (print)		

ADVISOR ASSURANCE: IF PRIMARY INVESTIGATOR IS A STUDENT

This is to certify that I have reviewed this research protocol and that I attest to the scientific merit of the study, the necessity for the use of human subjects in the study to the student's academic program, and the competency of the student to conduct the project.

Major Advisor Signature	Date	
Major Advisor (print)		

ACADEMIC UNIT HEAD: IT IS THE PI'S RESPONSIBILITY TO OBTAIN THIS SIGNATURE

This is to certify that I have reviewed this research protocol and that I attest to the scientific merit of this study and the competency of the investigator(i) to conduct the study.

Academic Unit Head Signature	Data
Academic Unit Head (print)	

FOR IRB USE ONLY	
R5 Approval	Date
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Florida Institute of Technology Institutional Review Board

Notice of Exempt Review Status Certificate of Clearance for Human Participants Research

Principal Investigator:	Beshoy Morkos
Date:	October 3, 2017
IRB Number:	17-148
Study Title:	Engineering motivation and time allocation study

Your research protocol was reviewed and approved by the IRB Chairperson. Per federal regulations, 45 CFR 46.101, your study has been determined to be minimal risk for human subjects and exempt from 45 CFR 46 federal regulations. The Exempt determination is valid indefinitely. Substantive changes to the approved exempt research must be requested and approved prior to their initiation. Investigators may request proposed changes by submitting a Revision Request form found on the IRB website.

Acceptance of this study is based on your agreement to abide by the policies and procedures of Florida Institute of Technology's Human Research Protection Program (<u>http://web2.fit.edu/crm/irb</u>) and does not replace any other approvals that may be required.

All data, which may include signed consent form documents, must be retained in a secure location for a minimum of three years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained on a password-protected computer if electronic information is used. Access to data is limited to authorized individuals listed as key study personnel.

The category for which exempt status has been determined for this protocol is as follows:

Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior so long as confidentiality is maintained.

- a. Information is recorded in such a manner that the subject cannot be identified, directly or through identifiers linked to the participant and/or
- b. Subject's responses, if know outside the research would not reasonably place the subject at risk of criminal or civil liability or be damaging to the subject's financial standing, employability, or reputation.

Appendix C Coding Tree



The full coding tree for the 69 codes identified by the qualitative exit interviews with the senior capstone design students is shown above. The coding tree is subdivided into three overarching themes: selection, process, and results.

The qualitative exit interview topic of "selection" outlined the student's reasoning for choosing their respective senior design project or team, including their feelings going into senior capstone design. The detailed coding tree for selection is shown below.



The "process" theme focused on the students' experienced while enrolled in senior capstone design. This was by far the largest of all of the themes, in which students referenced people very often as a factor. The detailed coding tree for process is shown below.



The "results" theme focused on the outcome of senior capstone design, which included student's future goals, skills that were acquired throughout the course of senior design, and reflections by the students regarding their overall experience. The coding tree for the results section is shown below.

