

A Quantitative Analysis of First Year Engineering Students' Courses
Perceptions and Motivational Beliefs in Two Introductory Engineering
Courses

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ABSTRACT

As a national initiative to support retention of engineering students, engineering programs have undergone a surge of revisions to their coursework in recent years, most notably in relation to first-year programs. These program modifications are generally intended to enhance student success in engineering, including both students' achievement and students' motivation to persist in an engineering degree. This study examines motivational constructs as it compares *two* versions (standard and revised) of an introductory engineering course taught in a general first year engineering program. The purpose of this dissertation is to examine students' course perceptions, students' Expectancy-Value beliefs, and the relationship between perceptions and beliefs in the two versions of an introductory engineering course. Students' perceptions of the class were measured at the course level using the MUSIC model of Academic Motivation, and students' Expectancy-Value beliefs were measured within the engineering domain level using Expectancy-value theory.

The dissertation is divided into three stages: In the first stage I provide a quantitative comparison of students' perceptions of the course, from students enrolled in each of the *two* versions of the course. In the second stage, I describe comparisons of Expectancy-Value engineering-related beliefs between students in each of the two versions of the introductory course, as well as within students in one of the courses. In the third stage, I develop structural models to test the relationship between students' perceptions of the introductory engineering courses and their Expectancy-Value engineering-related beliefs.

This study suggests three main outcomes: First, students' perceptions of success and caring are statistically and significantly different between the two versions of the course. Second, students' Expectancy-Value beliefs are discovered to have declined significantly in the standard version of the course, whereas in the revised version of the course, there are no statistically significant differences. Third, the fit indices of the models suggest a good model data-fit providing strong support for the hypothesis that students' perceptions of introductory engineering courses have effect on students' broader motivational beliefs. These outcomes have practical implications for students, instructors, and researchers in first year engineering education.

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GENERAL AUDIENCE ABSTRACT

The purpose of this dissertation study is to analyze students' course perceptions and students' motivation to persist in engineering. Several engineering programs in U.S have recently revised their coursework within first-year programs. One of the goals of these programs is to support students' engineering-related motivation. In this study, two groups of students were compared in relation to their academic motivation and perceptions of two versions of an introductory engineering course: standard and revised version. This dissertation work also includes an analysis about how students' perceptions of the courses were related to their engineering-related motivation. Students' perceptions of the courses were measured using an inventory based on the MUSIC Model of Academic Motivation and students' engineering-related motivation was measured through a survey based on the Expectancy-Value Theory.

The dissertation study was divided into three stages: In the first stage I provide a quantitative comparison of students' perceptions of the course from students enrolled in each of the *two* versions of the course. In the second stage, I describe comparisons of engineering-related students' motivation between students in each of the two versions of the introductory course, as well as within students in each of the courses. In the third stage, I develop statistical models to test the relationship between students' perceptions of the introductory engineering courses and their engineering-related motivation.

This study suggests three main outcomes: First, I found that students' perceptions of success and caring components are different between the two versions of the course. I also found that students' engineering-related motivation declined significantly in the standard version of the course, whereas in the revised version of the course, students' motivation did not change from the beginning to the end of the semester. Finally, I present evidence for the hypothesis that students' perceptions of introductory engineering courses have effect on students' engineering-related motivation. In other words, students' motivation to persist in engineering might be affected by their perceptions of introductory engineering classes.

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Chapter One

Introduction and Motivation

Introduction

“I find the course interesting, although a little confusing at first when it did not exactly fit my interests. As we moved onto drawings I found the course a little bit more manageable and interesting” (Peter, first year engineering student).

Students like Peter are abundant in first year engineering introductory courses. Helping first year engineering students develop foundational engineering skills while at the same time getting them excited about being an engineer is a challenge that many instructors, course developers, and other stakeholders within first year engineering programs encounter every day. No matter how much experience or knowledge faculty members or instructors in first year introductory engineering courses have, as faculty we need to remember that:

... although developing students’ technical expertise remains a priority, it cannot do so to the exclusion of students’ positive perceptions of the learning environment, their understanding of engineering as a career rather than a collection of information, and their meaningful identification with the profession (Jones, Osborne, Paretti, & Matusovich, 2014, p. 1353).

When trying to reach this goal, it is necessary to understand the extent to which students intend to engage in the classroom environment, and in the engineering profession. More importantly, it is necessary to understand how pedagogical and curricular approaches in first year engineering introductory courses affect both students’

perceptions of the learning environment and their motivational engineering-related beliefs.

Introductory engineering courses are one common element in many first-year engineering programs even with different matriculation practices. According to Chen, Brawner, Ohland, and Kikendall (2013), the highest level of classification of first year engineering programs in the U.S include at least two categories: 1) direct matriculation programs, and 2) general matriculation programs. According to this taxonomy, 52% from direct matriculation programs have required introductory engineering courses, while 24% from general matriculation programs require students to take one or more engineering courses. There is growing recognition in research that experiences related with courses taken in the first year, and the level of success in these courses, are directly related to students' achievement and retention, more than many other factors

In direct matriculation programs, students are admitted directly to a discipline. Their curriculum is usually very similar to that offered in general matriculation programs, and often include introduction to engineering courses; however, these introductory courses are not always mandatory (Orr et al., 2012). Conversely, in general matriculation programs, students are admitted as general engineering students without declaring a specific discipline. Students are enrolled in a common set of courses, typically including calculus, physics, chemistry, and an introduction to engineering sequence (Orr et al., 2012).

According to the taxonomy of engineering matriculation practices developed by Chen and colleagues (2013), of 390 U.S undergraduate institutions with ABET (Accreditation Board for Engineering and Technology) and EAC (Engineering

Accreditation Commission), 62% engineering programs adopt a direct matriculation practice, whereas 32% programs adopt a general matriculation practice (Figure 1). Of those institutions with general matriculation practices, 12% have established a general FYE, wherein students are identified as general engineering students; however, the institutions depend on some other support structures, for example, central advising (Chen, Brawner, Ohland, & Orr, 2013). Although this type of structure is not yet predominant in engineering programs, there is evidence that the adoption, or planned adoption, of FYE programs is growing nationwide, e.g. (Gipson et al. 2015; Nakatsu & Pascual, 2015; Robinson et al., 2015). Students in FYE programs are most likely to persist in their first choice of an engineering major, and tend to complete their engineering degree faster than students in direct matriculation programs (Orr et al., 2012). However, certain studies have suggested that students' motivation to persist in an engineering degree tends to decrease during the first year (Jones, Paretti, Hein, & Knott, 2010). It is necessary to understand how components, such as courses and pedagogical approaches, of first year programs are related to students' engineering-related motivational beliefs.

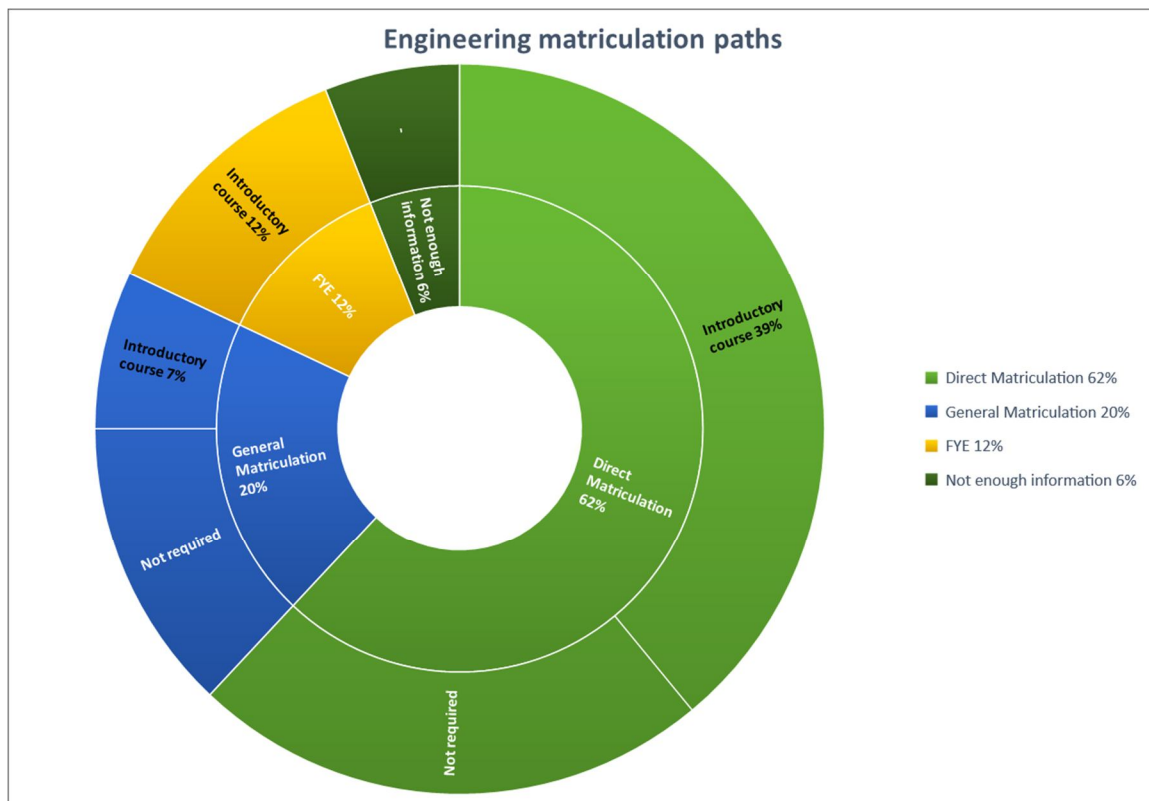


Figure 1. Representation of First Year Engineering Programs

Furthermore, higher education research has long suggested that student retention and success not only depend on students' cognitive abilities, but also on students' non-cognitive characteristics (Tinto & Goodsell, 1994). Cognitive characteristics are defined in this context as abilities and knowledge usually measured by achievement tests (Messick, 1979) while non-cognitive characteristics refer to traits not captured by assessments of cognitive ability and include qualities such as perceptions and motivation (National Research Council, 2013). Consequently, there has been an emphasis in both direct and general programs on "development of motivational first year courses, and student assistance programs outside the classroom" to better support students' motivation to persist in engineering (Brannan & Wankat, 2005, p. 1). This dissertation study is focused on students' non-cognitive characteristics, such as their perceptions of

introductory engineering courses and motivation to persist in engineering.

Statement of the Problem

Student retention has been studied for many years across multiple disciplines. In 1975, Vincent Tinto was one of the first to formulate a model of retention in higher education (Tinto, 1975). In his work, Tinto analyzed the process of student persistence/dropout decisions. Tinto's model explains the relationship between individual background characteristics and individual emotional characteristics. Tinto's work focuses on the importance of social and academic integration and how experiences at school, such as grade performance, and interaction with faculty and peers affect students' initial goals and values. Tinto called for future research that would consider similar variables to study retention (Tinto, 2005). Thus, the relationship between college persistence and individual, institutional, and environmental factors have been the subject of research for decades.

First year engineering programs have been cited as one of the initiatives that strongly contributes to retention in four-year public colleges (Habley & McClanahan, 2004). However, as previously noted, research also suggests that students' motivational beliefs decrease during the first year in an engineering program (Jones, et al., 2010). To effectively support students' motivation and retention, we need to better understand how the variety of experiences across the first year in engineering affect students' motivational beliefs.

During the last three decades, the engineering education community has strongly emphasized exposure to engineering for students during the first year in college (Blue et al., 2005). Since the transformation of Engineering Education in the mid-1990s with the

release of the Engineering Criteria (EC, 2000), and the launch of the Engineering Education Coalitions (EEC), the National Science Foundation (NSF) has urged innovation in engineering education. One of the proposals by the many participants of the EEC regarding systematic changes was the early introduction of engineering courses into the first two years of the engineering curriculum (Hall, Cronk, Brackin, Barker, & Crittenden, 2008). Since then, the inclusion of introductory engineering courses during a student's first year in an engineering program has grown nationwide. Still, current concerns about engineering retention and the preparation that engineering students require entail an examination of existing introductory engineering courses. In fact, numerous engineering programs have revised their approaches in first-year introductory courses in recent years, e.g. (Robinson et al., 2015; Weitzen, Willis, Maase, Johnston, & Rashid, 2015). Consequently, a broader view of the results of these changes, including incorporating students as stakeholders in the process, is necessary to offer a baseline for further discussion about how these changes allow for these courses to better meet the critical requirements of first year engineering programs.

This study focused on one university and its implementation of a *revised* version of an introductory engineering course. In this university, two versions of an introductory engineering course were offered during the same semester to the same cohort of first year engineering students. The course was redesigned with the goal, among other purposes, to “more effectively support student motivation to support retention” (unpublished internal document). Thus, empirical research is necessary to investigate how the course is meeting this goal. One way to accomplish this task is by examining how students, as key stakeholders in the process, perceive the two versions of the course. That is, to better

develop and design courses, it is necessary for engineering educators and administrators in first year programs to examine how students perceive these courses, and how those perceptions might be related to students' engineering-related motivational beliefs such as expectancy for success and identification with the engineering profession.

The engineering program included in this study fits into the taxonomy of engineering matriculation practices, developed by Chen and colleagues (2013), as an FYE program. Students are admitted to the college of engineering as general engineering students and are required to take an introduction to engineering sequence during the first year. In addition to first year introductory courses, this institution counts on general academic advising, and living learning communities for some students as part of the structure of its first-year program. Even though only 12% of the engineering programs accredited by ABET have a similar structure, the introductory engineering courses included in this study are representative and have served as model to other institutions with different first year engineering program structure (Krauss, Fries, & Karacal, 2016). However, the choice of including only one institution in the current study was to ensure that the institutional experience be similar for all participants. In addition, existing research has suggested that specific institutional characteristics influence the curricular development that a college might adopt (Lattuca & Stark, 2011). Thus, while the recommendations resulting from the analysis in the current study might be transferrable to other institutions with first year introductory courses, institutional characteristics will likely influence the way courses are designed.

Course Descriptions

This study compared data on students' perceptions and motivation to persist in

engineering between two groups of first year engineering students enrolled in two different versions of an introductory engineering course. Both courses were offered during the same semester at the same university. The following section will describe both versions of the course.

One of the versions of the introductory engineering course, for the purposes of this study referred to as *standard*, is a two-credit course required for all first-year engineering students. The course has no pre-requisites, but students must be enrolled in, or have credit for, a mathematics course to be enrolled in the course. The other version of the course for the purposes of this study referred to as *revised* was offered for the first time to approximately 25% of the incoming engineering students during the Fall semester (2013). Both courses were offered simultaneously. Students were placed randomly into either version of the course, *standard* or *revised*. The *revised* version of the course was equivalent to the *standard* one in that it was a two-credit course, a requirement for the program, and without pre-requisites. The two versions shared many characteristics; however, certain content, organization, assignments, and in-class activities were unique to each. Changes in the course to the *revised* version were grounded on existing literature, as well as the influence of experts in the engineering department (unpublished internal document). Table 1 shows a summary of the main similarities and differences between the two versions of the course explained in more detail in the subsequent sections. These features are based on the two courses' syllabi, as well as internal presentation materials of the engineering department, where the courses were developed. Specifically, I will describe features related to the setting, the content, in-class activities, and assignments in the two versions of the course.

Table 1.
Main Similarities and Differences Between the two Courses

Setting	Standard	Revised
Lecture	128 students	110 students
Workshop	32 students	28 students
Material access	Online access: Learning Management System (LMS)	Online access: Learning Management System (LMS)
Duration	15 weeks	15 weeks
Class material	Standard for all instructors	Standard for all instructors
Content	Design Process	Problem Solving skills
	Hands-on design	Modeling engineering systems
	Sustainable design project	Open-ended and ill structured problem
	Disciplines of the college of engineering	Contributions of different types of engineers in the development of engineering products or processes.
Class Activities and Assignments	Textbook problems, weekly presentations, and some written reports mainly concentrated on the design project	Summaries, memos, reports and create several concept maps focused on problem solving skills
	Plotting, finding, and reporting equations were done by hand, topics in programming such as loops, decisions, and vectors and the use of sensors to collect data were done using LABVIEW	Plotting, finding, reporting equations, topics in programming such as loops, decisions, and vectors and the use of sensors to collect data were done using MATLAB

Course Setting

The two courses shared very similar characteristics related to the setting. Both courses consisted of one large lecture forum (approximately 128 students for the *standard* course, and 110 students for the *revised* version), and one workshop environment (in

sections of approximately 32 students in the *standard* version versus 28 students in the *revised*). Both groups of students had access to the course materials through a Learning Management System (LMS) wherein they could access the course syllabus, class presentations, assignments, and grades. The duration of each course was 15 weeks. Both the lectures and workshop sessions were facilitated by using slides presentations, which were standard for all instructors of each of the courses. In the *standard* version of the course, there were nine lecture groups taught by five faculty members while in the *revised* version there were three lecture groups taught by three faculty members from the department. Each lecture had four accompanying workshop sections for both versions of the course. In the *standard* version, workshops were led mostly by graduate teaching assistants, instructors, and faculty members. In the *revised* version, workshops were led by mostly faculty members involved in the design of the new version of the course, and graduate teaching assistants.

Course Content

The course content for the *standard* version of the course was focused on the engineering design process. Students had to demonstrate a basic facility with hands-on design, and design evaluation, by working on a sustainable design project throughout the semester. Students further were required to exhibit a basic awareness of contemporary global issues and emerging technologies, and the impact of such on engineering practices. The course had an emphasis on knowledge of the disciplines of the college of engineering.

The *revised* version of the course was focused on problem solving rather than design process instruction. Problem solving focused on skills that have been identified as

transferrable, such as formulation, questioning, arguing, and evaluating, which were exposed as students worked on problems. Students were presented with how engineers use data, with an accompanying requirement of modeling engineering systems. It was required for all students in this *revised* course to compare and contrast the contributions of different types of engineers in the development of engineering products or processes. They were furthermore expected to articulate holistic issues that influence engineering, accomplished by having students work on open-ended and ill-structured problems wherein students chose from seven different challenges on topics including: an assembly plant, traffic control, water rocket launch, data acquisition on football helmet, obstacle avoidance robot, and hanging engine.

Other distinctions between the *standard* versus the *revised* course included the way that instructional methods and content were presented, such as teamwork, sketching, and ethics. In the *standard* version of the course, *teamwork* was mainly part of one class, wherein the approach for discussion was primarily adapted from Barkel (2004). The class was largely based on discussing basic principles of teamwork such as: 1) focus on the situation, not the person; 2) maintain self-confidence and self-esteem of others; 3) maintain constructive relationships; 4) take initiative to make things better; and 5) lead by example. In contrast, within the *revised* version of the course, teamwork discussions were part of several classes, versus one class in the *standard* version. The *revised* approach to teamwork was adapted from (Belbin, 2012), and was concerned with identifying individuals' behavioral strengths and weaknesses as they work more effectively within their teams. Belbin specifies nine team roles grouped into three categories: action, social, and thinking. These categories and their corresponding team

roles were used to develop the class discussion.

Other disparities include: in the *standard* version of the course one of the classes was focused on sketching, whereas in the *revised* version there was no formal instruction about this topic. Ethics was included in the *standard* version of the course by using a case study presented as a video followed by in-class discussion led by the workshop instructor, whereas in the *revised* version, there was no formal instruction on ethics.

The *revised* version dedicated one of the classes on information sources during which the college librarian presented guidance on use of the library, as well as finding, evaluating, and citing sources. The *revised* version of the course moreover included a guest speaker from career services wherein students were exposed to existing career services located within the institution. The new version also included a class dedicated to aiding students develop a pathway planner. This content was not included in the standard version of the course. Table 2 displays the course objectives from both versions of the introductory engineering course.

Table 2.
Course Objectives From the Standard and Revised Versions of the Introductory Engineering Course

Standard	Revised
<ul style="list-style-type: none"> • Demonstrate a basic understanding of the engineering design process; 	<ul style="list-style-type: none"> ▪ Solve problems using a variety of strategies
<ul style="list-style-type: none"> • Demonstrate basic facility with hands-on design and design evaluation, <u>accomplished by working in teams</u>; 	<ul style="list-style-type: none"> ▪ Model an engineering system
<ul style="list-style-type: none"> • Demonstrate a knowledge of the disciplines of the Virginia Tech College of Engineering; 	<ul style="list-style-type: none"> ▪ Contribute to team efforts
<ul style="list-style-type: none"> • Demonstrate an understanding of professional ethics and application to real-life situations; 	<ul style="list-style-type: none"> ▪ Compare and contrast the contributions of different types of engineers in the development of a product or process.
<ul style="list-style-type: none"> • Apply the scientific method to problem solving including use of software where applicable; 	<ul style="list-style-type: none"> ▪ Develop a plan of study for his/her undergraduate career
<ul style="list-style-type: none"> • Graph numeric data and derive simple empirical functions; 	<ul style="list-style-type: none"> ▪ Synthesize information from several sources in addressing an issue
<ul style="list-style-type: none"> • Develop and implement algorithms and demonstrate understanding of basic programming concepts; 	<ul style="list-style-type: none"> ▪ Communicate information effectively
<ul style="list-style-type: none"> • Demonstrate a basic awareness of contemporary global issues and emerging technologies, and their impact on engineering practice. 	<ul style="list-style-type: none"> ▪ Articulate holistic issues that impact engineering

Note: Blue connecting lines (solid) indicate similarities and red lines (dashed) indicate differences between the course objectives.

Class Activities

Other topics were similar in content, but the implementation means were decidedly different. For example, while in the *standard* version plotting, finding, and

reporting equations were done by hand, topics in programming such as loops, decisions, and vectors and the use of sensors to collect data were done using LABVIEW, all of these areas were covered using MATLAB in the *revised* version.

One notable difference regarding activities was the inclusion of product archaeology in the *revised* version of the course. Product archaeology is a pedagogical framework “that transforms product dissection activities by prompting students to consider products as designed artifacts with a history rooted in their development” (Lewis et al., 2013, p. 4). The rationale for this was to expose students to engineered products and designs, such as a cell phone, and to impress upon students that engineering problems are situated within social, regulatory, and economic requirements that cause those problems to be ill-structured. In addition, the product archaeology activity was intended to help students understand the roles of different engineers and recognize the differences and commonalities in different engineering fields (unpublished internal document).

Course Assignments

Assignments were focused on textbook problems, weekly presentations, and some written reports mainly concentrated on the design project in the *standard* version of the course. In the *revised* version of the course, students were asked to write several summaries, memos, reports and create several concept maps throughout the semester. Both groups of students were required to take two tests and a final exam. Appendix A shows a more detailed description about the class activities and assignments for both versions of the course.

The changes in the new version of the course were made grounded on research on academic motivation, metacognition, what it means to be an engineer, and problem

solving. One of the notable intentions in the new version of the course was to expose students to problem solving skills while students worked on a specific problem rather than the engineering design process. These problem-solving skills were grounded on existing research (see Jonnasen, 2010) and have been identified as transferrable to different contexts. These skills included 1) problem formulation, 2) questioning, 3) arguing, and 4) evaluating. Students were exposed to seven different open-ended problems and they could choose one of these problems to work during the semester; this idea is aligned with the concept of Empowerment included in the MUSIC Model.

Empowerment refers to the perception of having some choices while learning. Concept maps were used as part of the assessment of students' learning of problem solving skills. The use of concept maps has been proven to be useful to assess conceptual knowledge (Borrego, M., Newswander, C., McNair, L., McGinnis, S., & Paretto, M., 2009).

Although in both versions of the course students had opportunities to interact with each other and with the instructor, the amount of group work and interactions between students in the *revised* version of the course was greater than in the *standard* version. These changes were made to require additional teamwork in the revised version of the course; this gave students several opportunities to play different team roles and to deal with conflict.

In conclusion, the similarities and differences between the two versions of the course require an assessment of the results of these changes, including students' feedback as stakeholders in the process. Offering a baseline for further discussion about how these changes allow for these courses to better meet the critical requirements of first year engineering programs is a purpose of this study.

Theoretical Framework

This dissertation study requires a framework that allows studying both students' perceptions at the course level and motivational beliefs at the engineering domain level. For this reason, I used two frameworks in this dissertation, the MUSIC Model of Academic Motivation to study students' perceptions and the Expectancy-Value Theory to look at students' motivational beliefs about the engineering domain. The next section describes the theoretical frameworks used in this study.

Defining a Theoretical Framework

Academic motivation is defined as “a process that is inferred from actions and verbalizations, whereby goal-directed physical or mental activity is instigated and sustained” (Jones, 2009, p. 272). Understanding students' academic motivation is crucial for enhancing students' learning and students' choices in engineering. While there are many theories of motivation, the MUSIC model of academic motivation is especially useful to study students' perceptions of the course because each of the components of the model reveals aspects about the design of courses based on motivation theories (Jones, 2015). Unlike students' perceptions of the course, motivational beliefs are broader beliefs about the engineering domain, a higher level or context than perceptions about specific courses. I chose to use the Expectancy-Value model to study engineering-related motivational beliefs because this model has been shown to be related to important academic outcomes and persistence choices. For this reason, this study employed two theoretical frameworks, the MUSIC model of academic motivation was employed to look at students' perceptions of the courses and the Expectancy-Value model was used to study students' motivational beliefs at the engineering domain level. In the following

chapters, these two models and their respective relevancies to address the research questions in this dissertation study will be discussed in detail. Both of these frameworks offer different yet related insights towards understanding students' academic motivation and students' motivation to persist in engineering.

Purpose of the Study

The purpose of this study was to analyze how students' perceptions and engineering-related motivational beliefs differ between students enrolled in the *standard* versus the *revised* versions of an introductory engineering course, and to what extent students' perceptions of the courses predict their engineering-related motivational beliefs. Students' perceptions are defined as the extent to which students perceive their learning environment; students' perceptions were analyzed at the course level. It is important to study students' perceptions because students' perceptions of introductory engineering courses have been found to be related to their engineering motivational beliefs. Motivational beliefs are broader perceptions about the program or engineering domain. These beliefs in turn predict students' major and career goals in engineering (Jones, Tendhar, & Paretti, 2016).

I conducted a quantitative study with students participating in two different versions of an introductory engineering course designed, among other goals, to support students' motivation to persist toward an engineering degree. By getting quantitative evidence about: 1) how students perceive the two different courses, 2) how changes in students' engineering-related motivational beliefs differ between students enrolled in these two versions of the courses, and 3) how students' perceptions of the classroom are related to engineering-related motivational beliefs, the results of this study can contribute

in the design of introductory engineering courses.

There are three manuscripts in this dissertation study. Each manuscript addresses different, yet related aims. The aim for manuscript 1 was to analyze whether students' perceptions of the course differ between the *standard* versus the *revised* version of the introductory engineering course. This was measured by surveys filled out by students at the end of the semester for each course type. Students' perceptions of the classroom were measured using the MUSICSM model of Academic Motivation; referred to in this study as the "MUSIC model" (Jones, 2009). This model is based on five components: eMpowerment, Usefulness, Success, Interest, and Caring. The MUSIC model synthesizes ideas from several existing motivation theories into one source and suggests strategies to develop coursework and activities to increase students' academic motivation (Jones, 2009). The results of this study will be shared with faculty, instructors, and administrators with the purpose of contributing in the design and instruction of first year engineering introductory courses that support students' academic motivation and success.

The expectation is that practical implications derived from the MUSIC model based on the results of this study will serve as guidance for instructors and course developers in both general and discipline-specific first year engineering courses. The MUSIC model can be applied to any type of instruction and psychometric properties of the MUSIC inventory are similar across teaching approaches. In addition, institutions with different matriculation models shared the majority of frequently listed components of the courses, suggesting that content selection of first-year engineering courses is fairly consistent nationally (King et al., 2014).

The purpose of the second manuscript was to compare quantitatively students'

engineering-related motivational beliefs between a *standard* versus a *revised* version of an introductory engineering course. This was measured by motivational constructs included in a survey filled out by students at the beginning and end of the semester for each course type. This analysis also tracked any changes in these motivational beliefs over the semester by comparing students' motivational beliefs from the beginning to the end of the semester. Specifically, the analysis in this manuscript included students' Expectancy, Utility and Attainment value engineering-related beliefs based on the Expectancy-Value model developed by Eccles and Wigfield (2000). According to this model, the choice of persistence is closely linked to students' expectation and the value (Utility, Interest, Attainment, and Cost value) assigned to the academic task (Wigfield & Eccles, 2000). Expectancy-Value beliefs have been narrowly studied in engineering in the freshman level. The few studies in this context have reported that engineering students' expectancy and task value beliefs decrease over the first year. Hence, my hypothesis is that students' expectancy and task value beliefs decreased over the semester. In this study, I compared students' motivational beliefs between the two courses at the beginning and at the end of the semester. Additionally, I tracked students' motivational beliefs from the beginning to the end of the semester to investigate whether there is a difference in the changes of these beliefs. Unlike the students' perceptions analyzed in the first manuscript, these motivational beliefs are broader perceptions related to the program or engineering domain.

The purpose of the third manuscript of this study was to analyze whether students' perceptions of the different course type were related to students' Expectancy-Value beliefs at the engineering domain level. A previous study by Jones et al. (2014)

found that first year engineering cornerstone courses have positive effects on students' motivational beliefs in the engineering domain level. Cornerstone courses is a U.S. term for "design or project courses taken early, usually in the first year in the engineering curriculum" (Dym, Agogino, Eris, Frey, & Leifer, 2005, p. 103) such as the courses included in this study. By understanding how students' perceptions are related to students' motivational beliefs, faculty and instructors can integrate methods or strategies such as those suggested by Jones (2009) in the MUSIC model in their courses that mitigate the drop in first-year students' motivation to persist in engineering.

The purpose for each manuscript will be explained in further detail in the subsequent chapters. Figure 2 displays an overview of the manuscripts included in this study. By including data from both versions of the introductory engineering course, this study provides a unique opportunity to compare and understand differences in students' perceptions of the courses. The results of this study will help stakeholders include students' input for the overall assessment of the different curricular approaches in the courses.

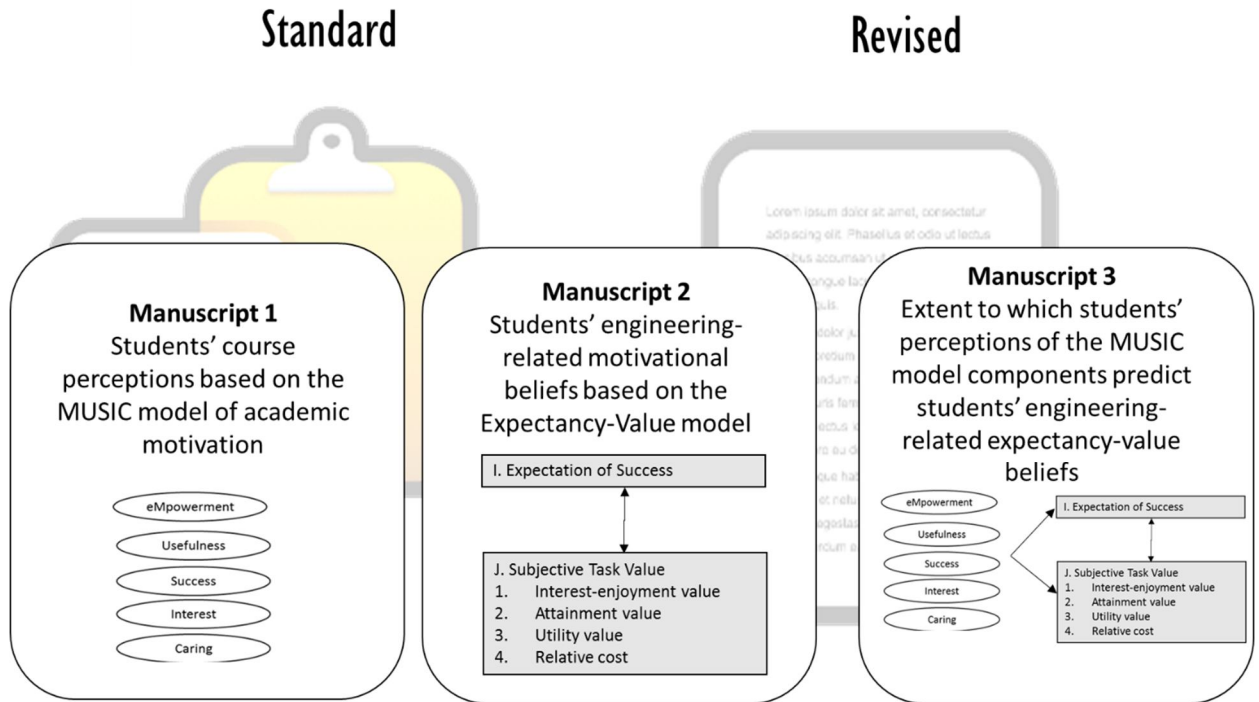


Figure 2. Overview of the Manuscripts Included in this Study.

Primary Research Questions and Research Design

The purpose of this study is to analyze how students' perceptions and motivational beliefs differ between students enrolled in the *standard* versus the *revised* versions of an introductory engineering course and to what extent students' perceptions of the classroom predict their engineering-related motivational beliefs. The overarching research question is "How do students' perceptions and motivation to persist in engineering differ between students taught in the *standard* versus the *revised* versions of an introductory engineering course?" Table 3 shows the primary research questions, the data collection, analysis, and expected outcomes for each question.

Table 3.
Primary Research Questions

Research Question	Data Collection	Analysis	Outcomes
RQ1: <i>How do students' perceptions of the course differ between students enrolled in standard versus revised versions of a first-year introductory engineering course?</i>	EOS	Descriptive statistics T-tests	Manuscript 1: Comparison of students' perceptions of the MUSIC model components between students enrolled in a <i>standard</i> versus a <i>revised</i> first year engineering introductory course.
RQ2: <i>How do changes in students' Expectancy-Value engineering-related beliefs differ between students enrolled in standard versus revised versions of an introductory engineering course?</i>	EOS; BOS	Descriptive statistics T-tests	Manuscript 2: Comparison of changes in students' Expectancy-Value engineering-related beliefs between students enrolled in a <i>standard</i> versus a <i>revised</i> first year engineering introductory course.
RQ3: <i>To what extent do first year engineering students' perceptions based on the MUSIC model components in a first-year engineering introductory course relate to students' Expectancy-Value engineering-related beliefs?</i>	EOS	Correlations; SEM	Manuscript 3: Evidence of extent to which students' perceptions based on the MUSIC model components in a first-year engineering introductory course predict students' Expectancy-Value engineering-related beliefs.

Note: EOS = End of Semester Survey; BOS = Beginning of Semester Survey; SEM = Structural Equation Modeling.

All the three research questions were addressed by analyzing motivational constructs included in a survey administered at the beginning and at the end of the semester when the introductory engineering courses were taught. Findings addressing each of the primary research questions will be presented separately in each of the manuscript.

Scope of the Study

The goal of this study is to analyze how students' perceptions of the MUSIC model components of an introductory engineering course differ between first year engineering students enrolled in a *standard* versus *revised* versions of the course. In addition, this study offers a comparison of changes in students' Expectancy-Value engineering-related beliefs between students enrolled in the two versions of the course. This study also includes determining the extent to which students' perceptions of the classroom using the MUSIC model component predict their Expectancy-Value beliefs at the engineering domain level. As such, this study includes quantitative statements to measure both students' perceptions of the courses and students' Expectancy-Value motivational beliefs at the engineering domain level. The intentions of this study do not include an evaluation of the content of the courses nor students' learning or achievement. The purpose of this study does not include comparing the methods of instruction by instructor type. Both courses include some aspects of Project Based Learning; however, the study of specific characteristics of this teaching method is outside of the scope of the present study, which compared data measuring *how* students perceived the two versions of the course.

Rather, the purpose of this study is to provide information about how students' perceptions of the courses and engineering-related motivational beliefs differ, if at all, and to test the hypothesis that these perceptions of the introductory engineering course have effect on students' motivational beliefs on the engineering domain level. This study is focused on general first year engineering students attending only one university. The generalization of the results is limited only to the first-year engineering students at this

university. This study is built upon previous research examining students' perceptions of an introductory engineering course, motivational beliefs, and the relationship between these two. This research study helps to assist faculty and instructors who are interested in the design and assessment of introductory engineering courses by offering a baseline study based on these two courses. While this study is far from providing any robust comparative assessment of which course is better, it can help to promote the implementation of specific practices that support students' motivation to persist in engineering.

This study also makes a contribution to the literature and to the field of engineering education by testing hypothesized relationships between students' course perceptions and motivational beliefs based on both frameworks: the MUSIC model of academic motivation and Expectancy-Value theory.

Significance of the Problem

This study is important for several reasons. This study looked at students' perceptions and motivational beliefs on two levels: the course level and the engineering domain level. First, by investigating students' perceptions of the two different courses, the results of this study give the interested stakeholders (faculty and administrators) a better understanding of how students perceived these courses, and how these perceptions differ between students enrolled in the *standard* versus the *revised* version of the course. This information can assist faculty and instructors who are interested in the design and assessment of introductory engineering courses. Specifically, faculty can have a better idea of how first year engineering students perceived these courses which is essential for the assessment and continuous improvement of introductory engineering courses. This

contribution may encourage other researchers to use similar methodologies in their research and/or assessment and design of their courses.

By measuring students' perceptions using the MUSIC model of motivation, practical implications are suggested. This information is especially useful for the instructors and developers of course content and pedagogy. Even though the courses included in this study might not be representative of courses in direct matriculation programs, the expectation is that practical implications derived from the MUSIC model based on the results of this study can serve as guidance for instructors and course developers in both general and discipline-specific first year engineering courses.

This study may provide quantitative evidence of significant relationships of students' perceptions of the courses, and their engineering-related motivational beliefs. Previous findings suggest that the course approach can affect students' broader motivational beliefs and subsequently their goals and career choices. Understanding how students' course perceptions are related to engineering-related motivational beliefs can aid instructors and course developers in identifying course curricula to improve students' motivation to persist in engineering. Finally, this study provides contributions to engineering education research by building upon existing literature on first year engineering courses and students' motivation to persist in engineering. In addition, this study provides contribution to the use of the Expectancy-Value motivational theory in the higher education setting with first year engineering students.

Limitations

When interpreting the results of this study, it is important to keep in mind its limitations. First, different instructors teach different sections of each course; this may

provide a difference in teaching styles that cannot be controlled. However, instructors were provided with standard syllabus and lessons material that might have resulted in a similar way to teach the classes. The reason for not disaggregating the data by instructors is that the scope of the current study does not include an evaluation of individual instruction, as well as protecting instructors' identities.

Second, the results of this study rely on self-reported data for all the variables. I acknowledge the imperfection of self-report data as it reflects subjectively from person to person. However, many researchers have established that self-report data is a credible means of examining students' perceptions (Kuh, 2005). This limitation is also minimized by including "reverse" questions on the survey, so that positive and negative responses cancel out any response bias. An example of reverse item is: "Knowing about engineering does not benefit me at all."

Another limitation of this study is related to the Expectancy-Value model constructs included in the existing dataset. The value part of the model consists of four elements: Interest, Attainment, Utility, and Cost value. Since this study is based on data that has already been collected, the interest element was omitted in the data collection. However, as a result of an exploratory factor analysis conducted in a previous study, the items used for measuring interest value and Attainment value were intertwined indicating that it seems that interest in studying engineering and interest in working as an engineer (Attainment) can be combined together (Li, McCoach, Swaminathan, & Tang, 2008) indicating that the interest element seems to be very close to the Attainment element. In addition, in this study the cost element is measured only with one item in the survey. Despite its importance, this construct has been the least studied of the four components of

subjective-task values (Wigfield, Tonks, & Klauda, 2009). Further research considering the inclusion of more items to better measure this construct is necessary.

Summary and Remaining Chapters

The selection of all the variables included in this study are grounded on existing research of first year students' academic motivation. The study includes three manuscripts with different research questions. The following three chapters represent the three manuscripts respectively, and include: a review of the context and specific research questions for the chapter, a summary of the literature and theoretical considerations relevant to the chapter, the methodology utilized, and a description of the data used to respond the research questions.

Chapter Two

A Quantitative Comparison of First Year Engineering Students' Course Perceptions

Introduction

Engineering educators usually place a great deal of importance and effort on designing pedagogies and instituting new approaches in the classroom. One example is the revision of pedagogical and curricular approaches in first year engineering introductory courses. However, we often undertake these efforts with little understanding of both the results of these revisions and how students perceive these courses.

Understanding students' perceptions of the classroom, or even a particular class, is important because, as instructors and researchers, we can improve or adjust teaching and assessment methods, as well as overall activities in the classroom that support academic achievement and students' motivation to learn and/or to persist in engineering. Previous findings suggest that students' course perceptions can affect their motivation to persist in an engineering career (Jones, Tendhar, & Paretti, 2016). The purpose of this manuscript is to compare students' course perceptions in two versions, *standard* versus *revised*, of a required introductory engineering course.

When students perceive a course to be useful for their short- or long-term goals, or if they perceive the course as having the material to be interesting or enjoyable, students tend to be more motivated to learn and to persist in a determined domain (Jones, 2009), for example, the engineering domain. There is a need to understand how to better support students' motivation to learn or to persist in their studies towards an engineering degree. This need is not new; there have been extensive calls about how to better support student retention in engineering programs (French, Immekus, & Oakes, 2005). Research

has suggested that student retention can be supported by enhancing not only students' cognitive characteristics, but also students' non-cognitive characteristics, such as motivation to persist in engineering (Tinto & Goodsell, 1994). As a result, engineering colleges have included specific initiatives to not only support students' achievement, but also to address students' motivation to learn, and to persist in achieving an engineering degree. As an illustration, engineering colleges have emphasized the "development of motivational first year courses, and student assistance programs outside the classroom" (Brannan & Wankat, 2005, p. 1). In other words, the design and revision of first year introductory engineering courses has been one of the practices put in place to better motivate engineering students to learn and to persist in studying toward attainment of an engineering degree. However, we know very little about the results of these changes and specifically how students actually perceive these newly revised courses.

The student sample pertaining to this study includes students in a general first year engineering program. In these programs, students take a variety of courses, typically including calculus, physics, chemistry, and an introduction to engineering sequence. Important to realize is that very often the introductory engineering sequence courses are the only courses in these programs wherein students enroll with "engineering" in the title (Jones et al., 2014). To put it differently, these courses usually represent the first exposure to engineering for thousands of future engineers enrolled in general engineering programs. The perceptions that students have about these courses may have a significant impact on students' decisions to persevere toward an engineering major, and possibly, into an engineering career in their futures. In fact, studies have indicated that students' perceptions of the practices in these engineering classes are related to their motivational

beliefs (Jones et al., 2014; Jones et al., 2016). Thus, one way to better support students' motivation to learn and to persist in engineering is by understanding students' perceptions of the learning environment in these courses.

In this study, students' perceptions are defined as the extent to which students recognize each of the components of the MUSIC (eMpowerment, Usefulness, Success, Interest, and Caring) model of academic motivation. Specifically, the extent to which students differentiate that:

- they have control of their learning (eMpowerment);
- the coursework is useful to their goals (Usefulness);
- they can succeed at the coursework (Success);
- the instructional methods and coursework are interesting (Interest); and
- others in the course (such as the instructor and their peers) care about learning (Caring) (Jones, 2015, p. 5).

Thus, students' perceptions were measured by using the MUSIC model inventory based on a questionnaire asking students about each of the MUSIC model components (Jones, 2015) (for a more detailed description of the MUSIC Model Inventory please visit <http://www.themusicmodel.com/inventory> website). A key point is that students' perceptions, not necessarily reality, is the subject in this study. In other words, I examined how students understand their class environment, or what students believe about the class.

Existing research on students' perceptions highlights that when students perceive a course to support their success, or short- or long-term goals, students tend to identify with a role in the content area of the class (Jones, Ruff, & Osborne, 2015). Consequently,

students who identify more with certain domain also tend to be more motivated to remain in that domain (Jones et al., 2014). Specifically in the engineering domain, some studies have concluded that perceived course experiences within first year engineering students are related to students' motivational beliefs, engineering major goals, and engineering career goals (Jones, 2014; Jones et al., 2016). Thus, it is important to document how students perceive the different approaches specifically in engineering classes for first year engineering students who are just beginning to understand what being an engineer means and what role they can play in the engineering field.

Because existing research indicates that the design of the courses can affect students' motivational beliefs and career choices, it is important to compare students' perceptions of these courses. Accordingly, this study sought to answer the following research question: How do students' perceptions of a course differ between students enrolled in standard versus revised versions of a first-year introductory engineering course?

This study is important for several reasons. Firstly, investigating students' perceptions of the two different courses can assist interested stakeholders, such as instructors of the course, faculty, and administrators, and include students' input for the overall assessment of distinct curricular approaches in the two versions of the course. In addition, this study can benefit our understanding of how students' perceptions differ among those enrolled in the standard versus the revised versions of the course. For this study, I used the MUSIC model of academic motivation developed by Jones (2009) to measure students' perceptions. Because the components of the MUSIC model are linked with specific motivational strategies, it is possible to identify practical implications

specifically for engineering introductory courses. This information is especially useful for the instructors and developers of the course content and pedagogy. In this study, I explored this research question by analyzing surveys administered at the end of one semester where both versions of the course were offered. Figure 3 shows a representation of the variables involved in this study (manuscript 1).

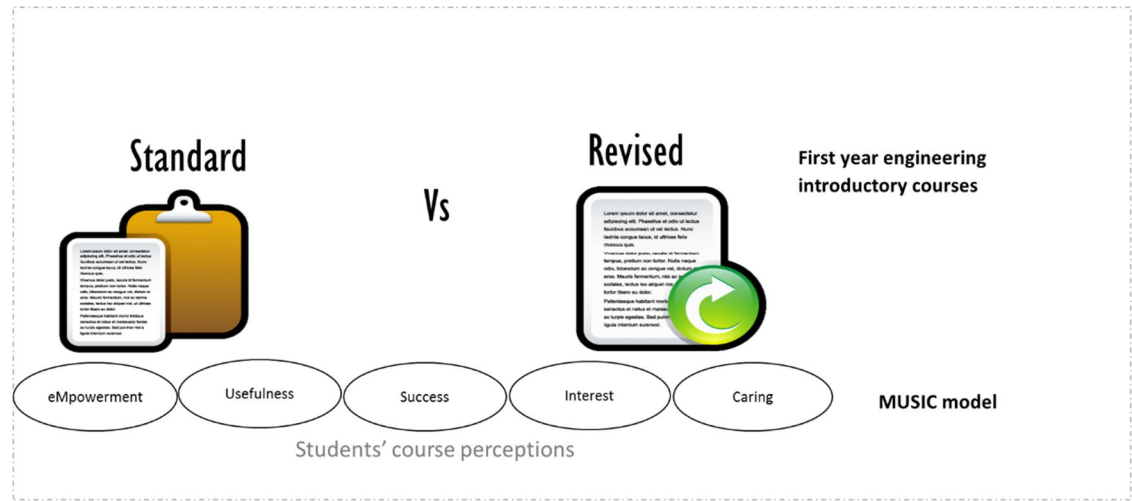


Figure 3. Representation of the Variables in this Study (Manuscript 1).

Framework: The MUSIC model of Academic Motivation

The MUSIC model of Academic Motivation is a model developed by Jones (2009) that includes existing conceptions of motivation that have been shown critical to students' motivation and engagement in the classroom (Jones, 2009; Ryan, 1991; Wigfield & Eccles, 2000). The model includes five key components:

- 1) eMpowerment;
- 2) Usefulness
- 3) Success
- 4) Interest; and

5) Caring (MUSIC).

The definition of motivation considered in the MUSIC model refers to circumstances in which learners choose to engage in activities that help them to succeed academically. The components of the MUSIC model correlate with numerous existing motivation theories; however numerous studies where factor analysis is conducted suggest that the components are different and unique. Table 4 shows the five components of the MUSIC model, their definitions and the motivation theories related to them.

Table 4.

Components of the MUSIC Model, Definitions, and Related Motivation Theories.

MUSIC model components	Definition	Related motivation theories
Empowerment	he or she has control over their learning	Self-determination (Ryan & Deci, 2000).
Usefulness	learning activities are useful for their short- or long-term goals	Expectancy-Value: Utility component (Wigfield & Eccles, 2000).
Success	he or she can succeed on a given academic task	Social cognitive theory: Self efficacy component (Bandura, 1986), Expectancy-Value: Expectancy component (Wigfield & Eccles, 2000),
Interest	the learning activity is enjoyable	Situational interest (Schraw, Flowerday, & Lehman, 2001).
Caring	others, particularly instructors, care about their learning	Relatedness (Ryan & Deci, 2000).

- *Empowerment* refers to “the amount of perceived control that students have over their learning” (Jones, 2009, p. 273). This component is derived from the self-determination theory (Ryan & Deci, 2000). Empowerment helps students perceive they have some control over their learning. According to Jones (2009), providing

students with some choices, and using their input to develop learning activities may increase their perception of control over their learning.

- *Usefulness* refers to students' perceptions of how a learning activity might be beneficial to them in the present, or in the future (Jones, 2009). This component is similar to the Utility value component of the Expectancy-Value motivation theory (Wigfield & Eccles, 2000). Students' academic motivation is usually affected by how useful they perceive the material to be for their short-term and long-term goals (Kauffman & Husman, 2004). Jones (2015) suggests that instructors should clearly explain how course materials are related to students' goals, and should furthermore offer students opportunities to demonstrate how such materials are related to their future careers, applied in the real world.
- *Success* refers to students' beliefs that they can overcome a given academic challenge if they put forth adequate effort (Jones, 2015). This component is based on various motivation theories such as: 1) Social-Cognitive theory, with a focus on Self-Efficacy (Bandura, 1986); 2) Self-Worth theory, with a focus on Achievement Motivation (Covington, 2000); and 3) Expectancy-Value theory, with a focus on Expectancy for success (Wigfield & Eccles, 2000). According to Jones (2015), students' perception of Success can be supported by clearly defining expectations for activities, providing honest and specific feedback, and being explicit when setting expectations (Jones, 2015).
- *Interest* refers to students' perception of enjoyment of a given academic task (Jones, 2009). In other words, students are interested in an academic task when they like the activity. Instructors can foster students' interest in an academic task

by considering both situational and individual interest. Situational interest is short-term curiosity that arises in a determined circumstance and environment (Schraw et al., 2001). Individual interest refers to an individual's psychological disposition associated with his/her preferences for activities (Hidi & Renninger, 2006). Situational interest can lead to individual interest. Instructors have the opportunity to develop their student's individual interests by creating opportunities for broad situational interests in the classroom.

- *Caring* refers to students' perceptions that others, particularly the instructors, are interested in their learning (Jones, 2015). This component is associated with the term *relatedness*, described by Ryan and Deci (2000) as "the desire to feel connected to others - to love and care, and to be loved and cared for" (p. 231). According to Jones, when students experience relatedness, they feel more comfortable asking and answering questions, benefiting engagement in learning activities (2009).

By using the MUSIC model, I aim to better understand certain contexts within the academic setting, and to furthermore to speculate what elements in the courses might influence students' academic motivational beliefs. More interestingly, each of the five MUSIC model components refers to a group of strategies that can be implemented in the classroom to support students' academic motivation (Jones, 2009). For example, providing students with choices during class within assignments, providing rationales when requiring students to do something, and avoiding controlling language are some of the strategies suggested by Jones (2009) to promote Empowerment in students. A more detailed list of strategies suggested by Jones (2015) for each of the components in the

MUSIC model can be found in “Motivating Students by Design: Practical Strategies for Professors”. In fact, Jones developed the MUSIC Model of Academic Motivation Inventory (MMAMI) with the purpose to help instructors in understanding motivation research. In addition, he intended to provide instructors with a tool that would offer both measuring students’ perceptions of the learning environment, combined with teaching strategies intentionally linked to each of the five components likely to motivate students (Jones, 2015).

The components of the MUSIC model have shown to be distinctive with different students’ samples; for example, Jones and Wilkins (2013) provided validity evidence for the use of the MUSIC model inventory with middle school students. Further, Jones and Skaggs (2016) validated the use of the MUSIC model inventory with a sample of 397 undergraduate students. They provided validity of the scores produced by the MUSIC Inventory with college students. Their results showed that each of the MUSIC model components was moderately correlated with the other four components, yet they demonstrated that each component was distinct (Jones & Skaggs, 2016). One example outside the United States is work by Mohamed, Soliman, and Jones, wherein they provided a cross cultural validation of the MUSIC model Inventory among Egyptian university students (Mohamed, Soliman, & Jones, 2013). Thus, validity evidence has been provided with different samples, including college students in the U.S., as well as within other cultures showing that the MUSIC model components are related yet can be considered separate constructs.

Further, some studies suggest that the MUSIC model inventory is useful in examining impact of engineering instruction on students’ motivation. For example, one

study employed the Usefulness component of the MUSIC model to examine how Problem-Based Learning (PBL) and traditional engineering pedagogies affected motivation of first year engineering students. Results in this study suggested that PBL - instruction fostered beliefs about the utility of critical design skills for first year engineering students (Matusovich, Paretti, Jones, & Brown, 2012). In addition, with the MUSIC model inventory, several instructional elements that foster students' motivation were identified in a capstone-engineering course. The results of this study suggested ways instructors might support students' motivation in PBL learning contexts, such as allowing students to choose their project topic, and to further communicate ways in which the projects are connected to real-world experiences, among other instructional elements (Jones, Epler, Mokri, Bryant, & Paretti, 2013). In brief, the MUSIC model inventory has been useful in examining the 'whats' and 'hows' regarding instructional elements or pedagogical approaches and their effect on students' perceptions and motivation.

The MUSIC model is useful for this study not only because of its overall value to academic motivation, but also due to its effective use with first year engineering students. Jones et al. (2014) documented that students who identified with the engineering domain were more likely to be motivated to pursue an engineering career. They also demonstrated that the MUSIC model consists of unique constructs in a first year engineering course (Jones et al., 2014). Students' perceptions of the MUSIC model components in a first-year engineering introductory course were related to their engineering identification. Some of the components influenced students' sense of belonging in the engineering community, and the 'Success' component was significantly

related with both engineering utility and program expectancy. In addition, engineering identification and program expectancy predicted students' choice of their undergraduate major, as well as their career goals in engineering (Jones, et al., 2015). These findings suggest that course approach can affect students' broader motivational beliefs and subsequently students' goals and career choices. Because a broader view of the results of changes in introductory engineering courses is necessary, the purpose of this manuscript is to compare students' perceptions of the two versions of the introductory engineering course in order to offer a baseline for further discussion about how these changes help introductory courses meet the needs of first year engineering students.

Methods

This section describes measures of students' perceptions of two versions of an introductory engineering course. These perceptions were based on each of the components of the MUSIC model of academic motivation (Jones, 2009). The purpose of this manuscript is to determine whether there are statistically significant differences in students' course perceptions between two groups of students: students who enrolled in the standard course and those who enrolled in the revised version of the introductory engineering course. This section will describe the methods by which data was collected, and the analytical methods that were used to test for differences between the two groups of students. Results from this analysis provides insight into how students perceived the two versions of the introductory engineering course.

Institutional Review Board

A research application form was submitted to the Institutional Review Board at the University. In order to protect the identities and privacy of the students included in

the study, the participants were assigned an anonymized, unique ID that does not allow the students to be identified. The Institutional Review Board reviewed the application and authorized the use of student records for this study.

Data Collection

This study used data previously collected by the engineering department, wherein the two versions of the introductory engineering courses were offered. Secondary data analysis is the use of existing data to investigate research questions others than those for which data were originally collected (Vartanian, 2010, p.3). The main advantages to using existing data is speed and economy. In addition, the existing data was collected from a population ideal for the purpose of this study. The existing data were used as measures of students' perceptions of each of the courses included in this study, which allowed for comparisons between the two groups of students. The pre-existing data used for this study had been collected through a survey conducted at the end of the Fall 2013 semester where both versions of the course were offered.

The Instrument

The purpose of this study is descriptive; the aim is to compare students' perceptions of the two versions of the introductory engineering course. The instrument used to collect the data was the MUSIC model of academic motivation inventory developed by Jones (2009). The instrument was used intact as it was developed which is appropriate for the context in this study.

The MUSIC model inventory is a self-report instrument that includes 26 items related to the five components of the MUSIC model (Empowerment, Usefulness, Success, Interest, and Caring). The five components have four to six items each:

- five Empowerment items;
- five Usefulness items;
- four Success items;
- six Interest items; and
- six Caring items.

All are rated on a 6-point Likert-type scale ranging from *strongly disagree* to *strongly agree*. Students were asked to answer the questions based on their experience in the course, including assignments, activities, reading, etc. The complete MUSIC model inventory can be found in <http://www.themusicmodel.com/inventory>. A sample item from each component is as follows in Table 5:

Table 5
Sample Items from the Components of the MUSIC Model

<i>Sample Item</i>	<i>MUSIC model component</i>
“I had the opportunity to decide for myself how to meet the course goals.”	eMpowerment
“The coursework was beneficial to me.”	Usefulness
“I was capable of getting a high grade in the course.”	Success
“I enjoyed completing the coursework.”	Interest
“The workshop instructor was available to answer my questions about the coursework.”	Caring

Students were invited to complete the MUSIC model inventory along with other demographic questions, motivational constructs, and questions about the course content and outcomes. Participants completed the survey during the last three weeks of the

course. An initial email, as well as two reminder emails were sent providing a link to the online questionnaire. The completion of the questionnaire was deemed a homework assignment; nonetheless, students were assured of their privacy and that instructors would not have access to the individual answers; students were informed that the questions had been designed to serve the department's evaluation of the course.

Validity and reliability.

Validity in quantitative research refers to the extent to which a concept is accurately measured (Creswell, 2012; Goodwin & Leech, 2003; Krathwohl, 1993) . In other words, it is important to ensure that the acquired results truly represent what was intended to be measured. In like manner, reliability refers to the consistency of the results in the administration of a test (Moskal, Leydens, & Pavelich, 2002). This refers to the precision of the data or consistency of data results. In the following section, I discuss these items in relation to this study.

Validity

Validity is considered to be the most fundamental consideration in the development of evaluation tests (Goodwin & Leech, 2003). Traditional forms of validity include: 1) content, 2) predictive or concurrent, and 3) construct validity. Content validity refers to the question: "do the items measure the content they were intended to measure?" (Creswell, 2013). Content validity means whether or not the variables (or content) that are intended to be measured are, in fact, being measured (Moskal et al., 2002). Then, predictive or concurrent validity answers the question: "do results correlate with other results?" (Creswell, 2013, p. 149). This type of validity evidence the extent to which results of an instrument correlate with a current or future event as a relevant

criterion (Moskal et al., 2002). This type of validity is usually examined by comparing the instrument against others that have already demonstrated validity and reliability. In other words, this type of validity indicates how well the survey measured items in reference to similar surveys. Finally, Construct validity responds to the question: “do the items measure hypothetical constructs?” (Creswell, 2013, p. 149). Construct validity is based on the instrument content (Goodwin & Leech, 2003). It refers to the extent to which the instrument shows evidence that supports that it is measuring the underlying constructs it was designed to measure (Moskal et al., 2002), or, in other words, does it properly measure what it was meant to measure? Construct validity has been defined as the demonstration that an instrument is measuring the construct it claims to be measuring. Some researchers consider that this type of validity includes all categories of validity (Messick, 1993). That is to say, construct validity can be examined for how it is linked to other sources of validity evidence.

Validity evidence of the MUSIC model inventory has been provided with different samples including college students in the US and other cultures and showed that the MUSIC model components are related yet can be considered separate constructs. Jones and Wilkins (2013) provided validity evidence for the use of the MUSIC model inventory with middle school students. Further, Jones and Skaggs (2016) validated the use of the MUSIC model inventory with a sample of 397 undergraduate students. They provided validity evidence for the MUSIC Inventory with college students. Their results showed that each of the MUSIC model components was moderately correlated with the other four components yet they showed the components were distinct (Jones & Skaggs, 2016). One example outside the United States is the work by Mohamed, Soliman, and

Jones where they provided a cross cultural validation of the MUSIC model Inventory among Egyptian university students among third and fourth year Egyptian faculty of education students. Their analysis produced the original five constructs included in the MUSIC model inventory providing additional validity evidence of the MUSIC model in an Arabic culture (Mohamed et al., 2013).

While the reliability and validity of this instrument in previous research contribute to the current validity and reliability of the survey, additional tests should be run to ensure the reliability and validity of the specific instrument and its use in the context of this study (Nunnally, 1978). For this study, the validity of the survey was addressed by evaluating construct validity. Constructs are defined as “processes that are internal to an individual” (Moskal et al., 2002, p. 351). These processes allow the individual to make sense of a determined concept. Thus, construct validity allows making implications from a sample to the higher order of constructs that they represent (Shadish, Cook, & Campbell, 2002). Researchers use several strategies to obtain evidence for construct validity. For example, using statistical procedures such as factor analysis is a common way to obtain evidence for construct validity. I conducted a factor analysis to address construct validity in this study.

Factors analysis refers to “a family of analytic techniques designed to identify factors, or dimensions, that underlie the relations among a set of observed variables” (Pedhazur & Schmelkin, 2013, p. 66). This statistical procedure examines interrelationships among items in order to identify underlying dimensions in a measure. With factors analysis, clusters of items that are highly correlated can be identified to have evidence that these items are measuring the same construct (Kratwohl, 1993).

There are two types of factor analysis: Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA). The type of factor analysis to be conducted depends on the anticipated findings of the analysis, whether the data is being explored or testing a specific hypothesis (Field, 2009). In EFA, to identify the most appropriate model, it is necessary to interpret the results because constraints are not previously placed in the model. In CFA, substantive constraints derived from a theory related to the construct to be measured are placed on the factor model (Kim & Mueller, 1978). In other words, in EFA all indicators have loadings (not necessarily meaningful ones) on all the factors, whereas in CFA the researcher can specify which indicators load in which factors in order to verify the factor structure previously identified (Pedhazur & Schmelkin, 2013).

For EFA, I conducted a principal component analysis (PCA) on the items included in the MUSIC Model Inventory. Principal component analysis is one of the preferred methods and a psychometrically sound procedure concerned only with establishing linear components within the data and how a particular variable might contribute to each factor. Orthogonal rotation (varimax) was used. Varimax rotation attempts to maximize the dispersion of loadings within factors (Field, 2009). This method of factor rotation was selected because it tries to load a smaller number of variables highly onto each factor resulting in more interpretable clusters of factors. This method is recommended for a first analysis because it is a good general approach that simplifies the interpretation of factors (Field, 2009, p. 644). Before conducting the PCA, it is necessary to check the sampling adequacy and the relationship between the variables as recommended by Field (2009). The Kaiser-Meyer-Olkin (KMO) measure is one of the

alternatives to verify the sampling adequacy for the analysis (Kaiser, 1970). The KMO statistic varies between 0 and 1. A value of 0 indicates diffusion in the pattern of correlations, thus factor analysis would be inappropriate. A value close to 1 indicates that the correlations are relatively compact and factor analysis should yield different still consistent factors (Kaiser, 1970). To check correlations between the variables, a Barlett's test of sphericity is suggested. This test indicates whether the correlation matrix of the variables is significantly different from an identity matrix. This is, indicating that there are some relationships between the variables included in the analysis, and therefore PCA analysis is appropriate (Snedecor, & Cochran, 1989).

Kline (2005) suggests the four following judgments of fit associated with the CFAs: (a) the model chi-square statistic, (b) the comparative fit index (CFI), (c) the standardized root mean square residual (SRMR), and (d) the root mean square error of approximation (RMSEA). The chi square statistic is used to test the fit of the model, with statistical significance indicating rejection of exact fit. Given complex models or large samples, the chi-square statistic is often found to be statistically significant, yet the model is a reasonable representation of the theory. Thus, additional fit indexes are used to control for the sensitivity of the chi-square statistic. The CFI varies between 0 and 1, with values closer to 1 indicating better fit, values above .90 representing reasonable fit, and values close to and above .95 representing good fit (Hu & Bentler, 1999). The SRMR also varies between 0 and 1 with values closer to 0 indicating better fit. SRMR values less than .05 indicate good fit (Byrne, 2001) and SRMR values less than .10 represent reasonable fit (Kline, 2005). The RMSEA also varies between 0 and 1, values closer to 0 indicate better fit. RMSEA values less than .08 indicate reasonable fit and values less

than .05 are considered good fit (Byrne, 2001; Kline, 2005).

Even though exploratory factor analysis has been conducted with the MUSIC model components, e.g. Jones et al., (2016), I conducted an exploratory factor analysis (EFA) to identify underlying factor structures as well as those items that did not fit into any existing factors. The purpose of this step is to explore the model that represents the specific data for this study (Lomax & Schumacher, 2012). Then, a CFA was conducted to confirm and refine the factor structure previously identified through EFA.

Reliability

In terms of reliability, Litwin (1995) discussed three types of reliability: 1) test-retest, 2) alternate-form, and 3) internal consistency. Test-retest reliability is concerned with the degree of consistency when the same test is applied to the same population on different occasions (Moskal et al., 2002). This type of reliability is difficult to estimate when the items or scales measure variables likely to change over a short period of time (Litwin, 1995). Alternate-form reliability refers to the use of differently worded forms to measure the same attribute. This could be simply changing the wording of a particular question without changing its meaning (Litwin, 1995). Lastly, internal consistency is based on the notion that the items, or subparts, of the instrument measure the same phenomenon (Pedhazur & Schmelkin, 2013). While test-retest and alternate form reliability are equally applicable to either type of measure, very often, practical problems arise when it is necessary to contact the same individuals twice to respond the same measure, or to measure similar items in different forms. For this reason, the conception of reliability based on a single administration of a measure or internal consistency reliability is generally used to obtain scores based on items measuring the same

phenomenon. Responses to items comprising a measure of a construct are thus expected to be internally consistent (Pedhazur & Schmelkin, 2013).

Cronbach's coefficient alpha is generally used to measure internal consistency reliability among a group of items combined to form a construct. Internal consistency is frequently used to demonstrate reliability of existing survey instruments. The reliability of the survey analyzed for this study was addressed by running an internal consistency test calculating this coefficient. While there is not a universal minimal value for Cronbach's coefficient, a value of 0.8 is generally accepted (Kline, 2013; Nunnally, 1978; Nunnally & Bernstein, 1994). It is necessary to be careful when using these general guidelines because the value of the Cronbach's alpha coefficient depends on the number of items in a construct (Field, 2009). For this reason, the Spearman-Brown formula was used in cases where a construct has less than 10 items since Cronbach's alpha is sensitive to number of items in a construct (Alsawalmeh & Feldt, 1999). That is to say, tests of fewer than ten items are unlikely to be reliable. Spearman-Brown formula is a correcting formula that compensates for this in constructs with less than ten items (Kline, 2013).

Participants and setting.

The participants in this study are general first year engineering students from the same cohort enrolled in either the standard or the revised version of a required introductory course at a large, public university in the mid-Atlantic United States. The engineering program included in this study fits into the taxonomy of engineering matriculation practices, developed by Chen and colleagues (2013), as a First Year Engineering (FYE) program. Students are admitted to the college of engineering as general engineering students, and are required to take an introduction to engineering

sequence during the first year. In addition to those first-year introductory courses, this institution counts on general academic advising to serve all students, and living learning communities to some students as part of the structure of its first-year program.

Students were randomly placed into either version of the course at the beginning of the semester. All students were emailed asking to complete the survey. The survey was open during a period of three weeks. Of the approximately 1,088 students enrolled in the standard version of the course, 93% students completed the survey and 74% consented participate in the study. Of the 338 students enrolled in the revised version of the course, 88% students completed the survey and 71% consented participate in the study. Table 6 displays information about response rates for each of the courses, whereas Table 7 shows participants' demographics by gender.

Table 6.
Response Rates

	<i>Standard</i>	<i>Revised</i>	<i>Total</i>
Total	1,088	338	1,426
Respondent	1,008 (93%)	299 (88%)	1,307
Consent	810 (74%)	240 (71%)	1,050

Table 7.
Participant Demographics MUSIC Model Inventory

<i>Gender</i>	<i>Standard</i>	<i>Revised</i>	<i>Total</i>
Female	23% (188)	15% (36)	22% (322)
Male	77% (620)	85% (204)	77% (1,113)
Total	808	240	1,435

Data analysis.

Descriptive statistics were analyzed to better understand data distribution and frequencies of the variables in the study. Completed participant scores were averaged by components of the MUSIC model, and were compared between the two samples of students. Data were analyzed using SPSS 24.0 software.

The purpose of this study is to compare students' perceptions of two versions of the introductory engineering course. Neither an evaluation of the *content* of the courses nor students' *learning* or *achievement*, are included in the scope of this study. Determining if the two groups of students have different levels of course perceptions remains the central purpose of this study.

Variables.

The independent variable Course Type represents which of the two courses each student is enrolled in, either the standard or the revised version. This variable was represented as a binary variable, with 0=standard, and 1=revised. The variables M, U, S, I, and C represent the examination of students' perceptions of each of the courses. These variables represent the average of each of the components of the MUSIC model:

Empowerment, Usefulness, Success, Interest, and Caring.

Statistical Tests.

A two-tailed, independent samples t-test, in which testing for possibility of a relationship is in both directions, was conducted to compare perceptions based on the MUSIC model component of students enrolled in the standard version to those who were enrolled in the revised version of the introductory engineering course. An independent t-test was employed to observe for statistically significant differences between means of two different groups (Field, 2009). The t-test employed in this study was performed with just one independent variable (the course), presented in two ways (standard or revised), and only one outcome (each of the MUSIC model components). Since the two samples came from the same student population, then it was expected that their means were roughly the same. Thus, the null hypothesis would indicate that the sample means were very similar, revealing there was no statistically significant difference between the two groups on the dependent variable. If the null hypothesis was retained, the two group means would differ only by sampling fluctuation, or by chance. An alternative hypothesis was that the two-sample means differ, wherein there was a statically significant difference between the two groups on the dependent variable.

Before conducting the t-test, preliminary analysis including: 1) Levene's test for equality of variances which measures how far out the data set is spread in the two groups of students, and 2) Shapiro-Wilk's test of normality were performed. Results of this preliminary analysis were used to determine whether the t-test should assume equal or unequal variances, as well as normal or no-normal data distribution.

Results

Construct validity.

Exploratory factor analysis

I conducted a principal component analysis (PCA) on the 26 items in the MUSIC model inventory. Orthogonal rotation (varimax) was used. Varimax rotation attempts to maximize the dispersion of loadings within factors (Field, 2009). The Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis, KMO= 0.951 and all the KMO values for individual items were >0.87, which is well above the acceptable limit of 0.5 (Field, 2009). Barlett's test of sphericity $\chi^2(325) = 17913.27$, $p < 0.001$ was significant indicating that there are some relationships between the variables included in the analysis, and therefore PCA analysis was appropriate. I run an initial analysis to obtain eigenvalues for each component in the data. Four components had eigenvalues over Kaiser's criterion of 1 and in combination explained 72.42% of the variance, with factor 1 contributing 46.81%, factor 2 contributing 13.56%, factor 3 7.08%, and factor 4 4.95%. The pattern matrix is shown in Table 8. Overall, the results suggested that three of the factors had the highest loading on the factor with the other items in the same subscale. This is, all of the Caring items (C1-C6) loaded highest on factor 2, all of the Empowerment items (E1-E5) loaded highest on factor 3, and all of the Success items (S1-S4) loaded highest on factor 4. Usefulness and Interest items (U1-U5 and I1-I5 respectively) loaded into the same factor. This result confirms findings from an EFA conducted in a study by Tendhar, Singh, and Jones, (2017) that included the same dataset which also showed that all the Usefulness and Interest items loaded together (Tendhar et al., 2017). Consequently, these two components were combined as a single factor. This

analysis was conducted on the entire sample of students in the standard version of the course. Table 8 shows the indicators variables loading onto each factor.

Table 8.
Factors Loading from the EFA- MUSIC Model Indicators

	<i>Factors</i>			
	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>
U2	.863			
U1	.856			
U4	.819			
U5	.813			
I6	.807			
U3	.795			
I1	.795			
I5	.760			
I2	.744			
I4	.715			
I3	.660			
C5		.849		
C6		.848		
C4		.839		
C2		.828		
C3		.766		
C1		.751		
E2			.782	
E4			.728	
E3			.726	
E5			.706	
E1			.579	
S1				.822
S3				.819
S4				.797
S2				.763

Note. Only highest coefficients are shown for each item (all loadings > 0.500).

Therefore, results of the EFA showed that all of the MUSIC model items loaded cleanly onto three different factors except for Usefulness and Interest items that loaded into the same factor suggesting that these items best explained its respective factor when grouped together. Factors loadings shows the relative contribution that an item makes to a factor/component.

Confirmatory factor analysis

Confirmatory factor analysis (CFA) was conducted and the measurement model was re-specified to improve the model-data fit, which is a common statistical practice. Specifically, I removed six of the 26 items related to the MUSIC model components. I used AMOS Version 24 to conduct the CFA using the maximum likelihood estimation method. All the latent variables (Empowerment, Usefulness, Success, and Caring) were allowed to covary. The fit indices were as follows: SRMR= 0.04, RMSEA= .057, and CFI= .966. These scores indicate a good model-data fit (Browne & Cudeck, 1993; Byrne, 2001; Hu & Bentler, 1999; Kline, 2005). Figure 4. shows the final model.

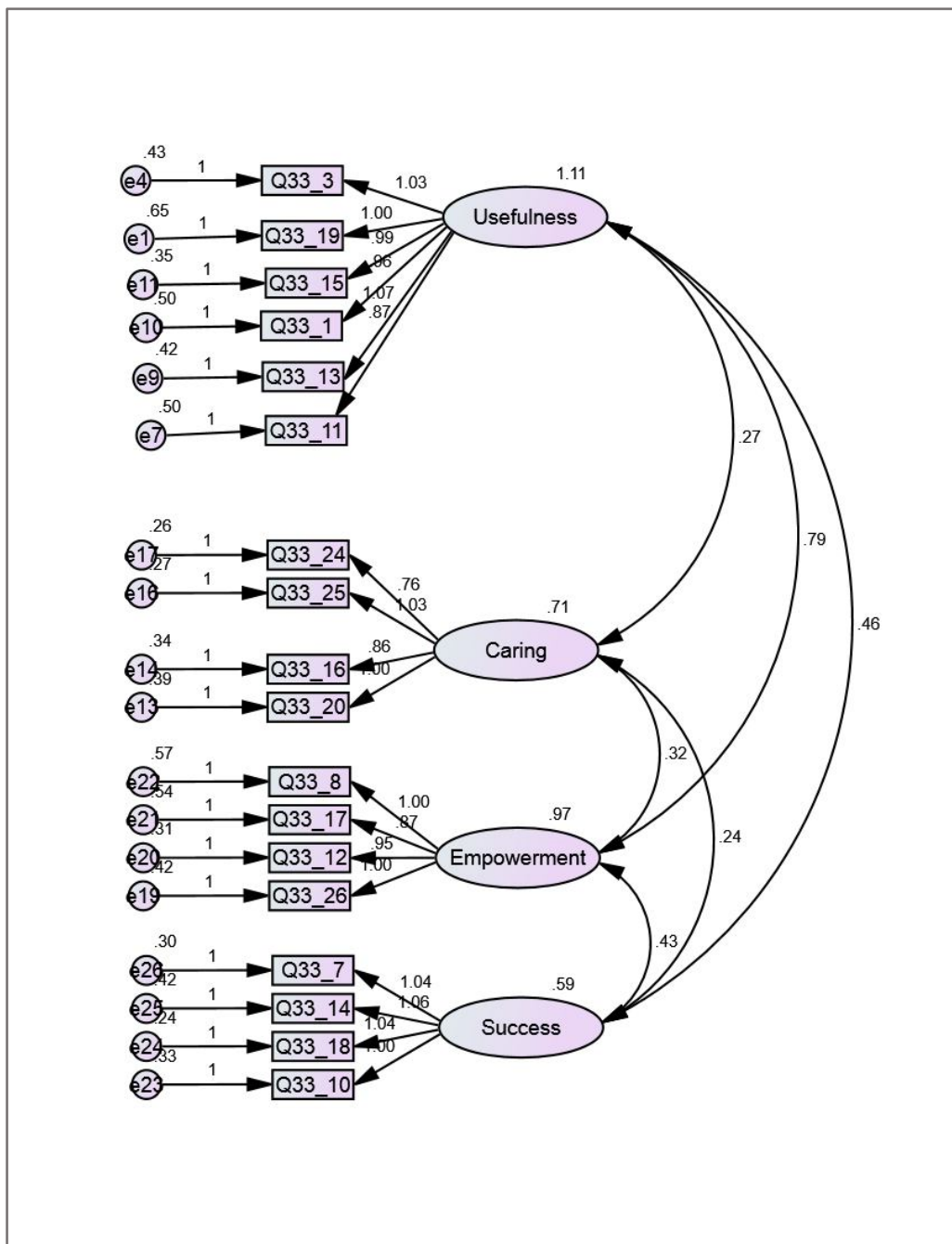


Figure 4. Model Resulting from the CFA: MUSIC model.

The Usefulness and the Interest components were collapsed into one single component denominated Usefulness. The model provided a good fit to the data as indicated by the model fit indices supporting the hypothesis that these four components are theoretically distinct constructs.

Reliability.

All the components of the MUSIC model showed acceptable Cronbach's alpha values for each construct and course type. Results are shown in Table 9. All Cronbach's coefficients resulted >0.8 indicating stability of the scales. In all cases, the Spearman-Brown formula was used to assess reliability values since all the scales had fewer than 10 items (Alsawalmeh & Feldt, 1999).

Table 9.

Internal Consistency Reliability-Cronbach's Alpha

<i>Construct</i>	<i>N of Items</i>	<i>Cronbach's Alpha</i>	<i>Course Type</i>
Empowerment	4	.88	Standard
		.88	Revised
Usefulness	6	.93	Standard
		.92	Revised
Success	4	.88	Standard
		.89	Revised
Caring	4	.87	Standard
		.84	Revised

Independent T-test.

For the sample analysis of difference of means, independent sample student's t-test was used. Before conducting the t-test, preliminary analysis including: 1) Levene's test for equality of variances which measures how far out the data set is spread in the two groups of students, and 2) Shapiro-Wilk's test of normality were performed. Results of this preliminary analysis was used to determine whether the t-test should assume equal or unequal variances, as well as normal or non-normal data distribution. For the MUSIC variables, the variances were equal for the standard and the revised groups, non-

significant. Thus, the assumption of homogeneity of variance was assumed. Then, the MUSIC variables were all significantly non-normal $p < 0.05$. Since the data is not normally distributed, a Wilcoxon test was conducted. P-values less than 0.05 were considered significant. Due to a disproportion between the number of males and females in the two versions of the courses (see demographics Table 7), the sample was weighted by gender to correct this imbalance (Babbie, 2015). Effect sizes were also calculated to demonstrate “the importance” of any differences since statistical significance can be affected by sample sizes (Cohen, 1988; Rosnow & Rosenthal, 1996). Originally, ranges for effect sizes were defined as small: $d = 0.2$, medium, $d = 0.5$; and large, $d = 0.8$ (Cohen, 1988). However, a meta-analysis study developed simultaneously with Cohen’s work suggested to adjust ranges of effect size as they applied to social science research as: near zero $d \leq 0.10$; small $0.11 < d \leq 0.35$; moderate $0.36 < d \leq 0.65$; large $0.66 < d \leq 1.0$; and very large $d > 1.0$ Hyde (1985). Descriptive statistics for the MUSIC model components for each course were also calculated and a summary of these results are listed in Table 10.

Table 10.

Descriptive Statistics of the Components of the MUSIC Model by Course Type

	<i>Course Type</i>	<i>N</i>	<i>Mean</i>	<i>SD</i>	<i>Mdn</i>	<i>Z</i>	<i>P value</i>	<i>Effect size Cohen's d</i>
Empowerment	Standard	808	4.27	0.96	4.40	-.808	0.42	0.07
	Revised	240	4.20	0.99	4.40			
Usefulness	Standard	808	4.10	1.11	4.20	-0.52	0.96	0.01
	Revised	240	4.09	1.14	4.20			
Success	Standard	808	4.66	0.84	4.75	-2.98	0.00*	0.15
	Revised	240	4.53	0.92	4.75			
Caring	Standard	808	4.98	0.78	5.00	-3.55	0.00*	0.16
	Revised	240	5.10	0.73	5.17			

Note: * $p < 0.05$.

Empowerment and Usefulness levels in students in the *standard* course did not differ significantly from students in the *revised* version. Success levels in students in the *standard* course were significantly higher than in students in the *revised* course. Caring levels in students in the *revised* course were significantly higher than in students in the *standard* course. The effect sizes for these differences are considered small for all cases. These small sizes suggest that the importance of the significance is small, the significance may be enhanced by a large sample size.

Discussion

The aim of this manuscript was to investigate if there was a significant difference in students' perceptions based on the MUSIC model components between students enrolled in the standard and revised versions of a first-year introductory engineering course. Data analysis indicated that differences in only two components, Success and Caring, were statistically significant. The mean score for Empowerment, and Usefulness components were somewhat lower for the revised version of the course than the mean score for those students in the standard version. However, these differences were not statistically significant ($p=.42$, $.96$ respectively).

Empowerment: Results revealed a non-significant difference between the means of the two groups of students for the Empowerment component, $p>0.05$. The mean for the Empowerment component was lower for students in the *revised* version of the course than the mean for students in the *standard* version ($M= 4.20$ and 4.27 respectively). According to Jones (2009), Empowerment refers when students perceive that they have some choices over the way they learn. Empowerment is related to research based on self-

determination theory (Ryan, 1991; Ryan & Deci, 2000). It refers to the need to feel autonomous. Jones suggests to develop a curriculum wherein students are given choices regarding their learning process (Jones, 2009).

Although the differences in the means of the two groups of students were not statistically significant, results can be interpreted according to their practical significance. The mean for the Empowerment component was lower for students in the *revised* version of the course. This is interesting since students in this version of the course might have had more opportunities for choices related to their semester project when compared to their counterparts in the *standard* version. Jones' suggestion about given choices is also accompanied with the caveat that while providing choices is important, providing too many choices can sometimes be overwhelming for some types of students. This might be especially true for students coming from high school to college who can feel overwhelmed with their choices. Jones also cautions that choices need to be appropriate for students' abilities. This statement might be related to students' abilities to handle uncertainty in the *revised* version of the course. They were working on an ill-structured project, which often possessed either no clear solutions or multiple solutions with a certain degree of uncertainty about what was necessary for their solutions. In the *standard* version of the course the design project was also open-ended; however, it was more structured and had fewer choices than the project in the *revised* version. This might have influenced students' perceptions of Empowerment. Jonassen (2011) suggests scaffolding support for learners working to solve ill-structured problems. Students may feel more motivated receiving intensive support and/or perhaps with fewer choices until they obtain more confidence. These speculations require further research.

Usefulness: Results revealed a non-significant difference between the means of the two groups of students for the Usefulness component, $p > 0.05$. According to Jones (2009), Usefulness refers to students' perceptions that the course content, assignments, or activities are useful to their goals in life. This component is tied to the Utility value construct developed by Wigfield and Eccles (2000). It refers to the potential ways students believe that they can benefit from coursework. Instructors can help students to see the Utility in coursework by relating class activities to students' goals (Jones, 2015). The mean for this component was lower for students in the *revised* version of the course than the mean for students in the *standard* version ($M = 4.09$ and 4.10 respectively). In the *standard* format, assignments were focused on textbook problems, weekly presentations, and some written reports mainly concentrated on the design project while in the *revised* version of the course students were asked to write several summaries, memos, and reports, and create several concept maps throughout the semester. Students may have perceived assignments in the *standard* version to be a bit more useful for their goal of being an engineer. For example, concept maps were used as part of the assessment of students' learning of problem solving skills in the *revised* version of the course. The use of concept maps has been proven to be useful to assess conceptual knowledge (Borrego et al., 2009). However, first year students might not find it useful to learn how to elaborate a concept map for their engineering related goals. Although we may think that it is obvious as to why the knowledge or skills students are learning are useful, the students themselves may not. Explaining the purpose and the importance of each assignment in writing is especially important in these cases.

Success: The Success component was significantly different between the two

groups of students. This component was lower in the revised course (M= 4.53) than in the standard version (M= 4.66). According to the MUSIC model of Academic Motivation, the Success component refers to students' beliefs that he or she can succeed if they put forth adequate effort. This includes students' beliefs in their own ability to complete assignments and class activities by investing a reasonable amount of effort. This component is related to self-efficacy as described in social cognitive theory (Bandura, 1986) and the Expectancy component in Expectancy-Value theory (Wigfield & Eccles, 2000). These theories refer to a student's belief that he or she can succeed on a given academic task. Some of the instructional strategies suggested by Jones (2009) to support students' perceptions of Success include setting reasonable expectations, showing examples from former students, being explicit when describing your expectations and communicating with students, and matching the difficulty levels of class activities and assignments with the abilities of the students. It is possible that, because this was the first time the new version of the course (revised) was offered, many of these aspects were not possible to implement; for instance, offering students examples of assignments from former students. The time when the survey was applied could also have influenced students' perceptions of this component. The survey was open during the last four weeks of the semester, and most of students completed the survey next to the last week of the semester; a concern is that the ability of students to accurately estimate their level of Success at the end of the course might be influenced by the level of uncertainty about their grades in the course. While this holds true for both groups of students, the level of uncertainty could have been higher for the group in the *revised* version of the course simply because of all the new things to which students were being exposed. However,

additional research is needed to investigate why the difference in the perception of Success.

Caring: The Caring component was also statistically different between the two groups of students ($p < .05$). Caring refers to students' perceptions that their instructor is interested in their learning. This component was significantly lower in the standard course ($M = 4.98$) than in the revised version of the course ($M = 5.10$). Caring is related to *relatedness*, described by Ryan and Deci (2000) as "the desire to feel connected to others - to love and care, and to be loved and cared for" (p. 231). According to Jones, when students experience relatedness, they feel more comfortable asking and answering questions, benefiting engagement in learning activities (2009). It is difficult to speculate why Caring was significantly different in the two groups of students since the data include different instructors teaching different sections of each course; further research could disaggregate data by instructors providing more insight for this finding. However, it is important to highlight that most of the instructors in the *revised* version were also involved in the design of the course; this could have created a sense of connectedness with the material being taught and with the activities implemented in the classroom. This might have impacted the way students perceived the Caring component in the *revised* version of the course. The Caring component is highly related to individual instructor style; however, a good practice could be to involve instructors in the design of content and activities in their classes. Fostering a class culture where students feel challenged and at the same time comfortable participating in class could be another general practice for instructors to implement to better support students' perception of this component. Caring strategies suggested by Jones (2015) include being approachable and relatable to

students, ensuring that students feel respected by you and other students, showing students that you care about whether they achieve the course objectives, and considering accommodating students when they experience extraordinary events (Jones, 2015, p.92).

Conclusions and Future Work

Given the importance of students' course perceptions in their motivation to pursue an engineering degree, steps should be taken to continue the assessment of these courses to ensure that students are given the opportunity to have a better perception of their learning environment. The MUSIC model presents an inventory that could be implemented in the assessment of any course; psychometric properties of the MUSIC inventory are similar across teaching approaches. The results of this study can help stakeholders include students' input for the overall assessment of the different curricular approaches in the courses. A broader view of the results of these changes is necessary for further discussion about how these changes make these introductory courses better to meet the critical requirements of first year engineering programs

This study compared data of students' perceptions of the first time the new version of the course was offered, analysis with the following cohort data should be carried out. Even though the effect size was small, those with design and curriculum development responsibilities should take these results into account when designing first year engineering introductory courses. In education, if it could be shown that making a small change would improve students' motivation to learn and persist in a degree by a small effect size then this could be a very significant improvement, particularly if the improvement can be sustained over time.

Limitations

The analysis in this study did not specifically include mapping of the content and structure of the two versions of the course with each of the MUSIC model components. A clear representation of which content or activities support the MUSIC model components could have given more insights about what type of content and/or activities were more appropriate to support these groups of students' academic motivation. Since this representation was not explicitly included, it was not possible to know which specific elements in the courses impacted students' perceptions of these components. An examination including how the content and activities in the courses meet each of the MUSIC Model components could give valuable information about how to improve the design of the courses.

Different instructors taught different sections of each course included in this study. This implied a difference in teaching styles that cannot be controlled. This is especially important because some components of the MUSIC model rely heavily on perceptions of instruction. The choice of not disaggregating data by instructor was made to protect instructors' identities and because the scope of the current study did not include an evaluation of individual instruction. However, in terms of assessment of the courses, it would be valuable to disaggregate data not only by instructors but also by gender and ethnicity in order to uncover overall trends and patterns and to set program-wide goals or targets that improve overall first-year engineering students' academic motivation.

Results of this study rely on self-reported data for all the variables. Self-report data is generally considered to be subjective from person to person. However, many researchers have established that self-report data is a credible means of examining

students' perceptions especially if the questions are about recent events (Kuh, 2005). That was the case for this study, the MUSIC Model Inventory asking about students' perceptions of the courses was completed during the last three weeks of the courses' duration.

Chapter Three

A Quantitative Analysis of First Year Engineering Students' Engineering-Related Motivational Beliefs

Introduction

Research suggests that motivational beliefs impact people's choice of whether to engage in a domain or a task (Wigfield & Eccles, 2000). Specifically, engineering-related motivational beliefs, unlike perceptions about a specific engineering course, are broader views about the engineering domain, such as beliefs about becoming, or pursuing a career as an engineer. Some of these beliefs have been shown to predict career intentions and occupational choices (Jones et al., 2014). In view of the importance of students' success to increase the national engineering workforce, information about students' engineering-related motivational beliefs is imperative.

Moreover, for most students, engineering introductory courses are frequently the first exposure to the subject matter. Likewise, these engineering courses are commonly a vital part of the engineering domain for first year engineering students; however, research suggests that curriculum difficulty, poor teaching and advising, and lack of belonging in engineering are major factors leading students to abandon engineering (Marra, Rodgers, Shen, & Bogue, 2012). Hence, a valid question that often arises is: how can introductory engineering courses better support first year students' motivational beliefs about engineering? This goal is often not explicitly assessed. The purpose of this study is to examine possible differences in students from a revised version of an introductory engineering course modified, among other goals, to better support students' engineering-related motivational beliefs. Specifically, I expect to examine whether there are

statistically significant differences in students' engineering-related motivational beliefs between students enrolled in either the *standard* or the referred-to *revised* version of such an introductory engineering course. By exploring these possible differences between the two groups of students, it is possible to expand our understanding about the factors that contribute to engineering-related motivational beliefs of first year students.

Motivational beliefs have been used to better understand how persistence occurs in engineering studies. The Expectancy-Value model developed by Wigfield and Eccles (2000) is a useful framework to understand students' motivation and/or their choice to persist in an engineering education. Although several studies related to the construct of persistence in engineering are using motivation theories as a framework, most of them have studied the relationship between achievement and persistence (Alias & Hafir, 2009; Hutchison-Green, Follman, & Bodner, 2008; Hutchison, Follman, Sumpter, & Bodner, 2006). However, achievement is known to be an insufficient predictor of persistence in engineering (Atman et al., 2008; Lichtenstein, Loshbaugh, Claar, Bailey, & Sheppard, 2007). Abilities, or achievements, are not the only characteristics that might encourage, or limit, student persistence in engineering. The constructs in the Expectancy-Value model provide a more explicit way to examine students' interest in choosing an engineering degree, and in their decisions to persist (Matusovich, Streveler, & Miller, 2010).

We need a better understanding of how to link pedagogical practices to students' choice to become engineers (Sheppard, Macatangay, Colby, & Sullivan, 2009). It is challenging to retain students when we have little understanding of students' goals, objectives, and decision-making criteria (Matusovich et al., 2010). Again, to enhance the

overall engineering workforce, we need a better understanding of persistence choices. Research suggests that factors such as engineering expectancy-values may be adequate to investigate students intentions and choice of activities (Eccles, 1983; Meece, Wigfield, & Eccles, 1990). The purpose of this study is to compare students' Expectancy-Value engineering-related beliefs between two groups of students: those enrolled in the *standard* versus those enrolled in a *revised* version of an introductory engineering course. This study sought to answer the following research question:

How do students' Expectancy-Value engineering-related beliefs differ between students enrolled in the standard versus revised versions of an introductory engineering course?

It is important to emphasize that this study does not address hypothesis testing of the effects of the introductory engineering course on students' Expectancy-Value beliefs. According to the Eccles' model, Expectancy-Value beliefs are shaped by many contributing factors: past experiences, socializers, and identity beliefs that are not included in this analysis (Wigfield & Eccles, 2000). Rather, this study offers a comparison of engineering Expectancy-Value related beliefs between students in a *standard* versus a *revised* version of an introductory engineering course. The analysis also tracks any changes of these motivational beliefs by comparing students' motivational beliefs from the beginning to the end of the semester. Figure 5 shows the representation of the variables in this manuscript.

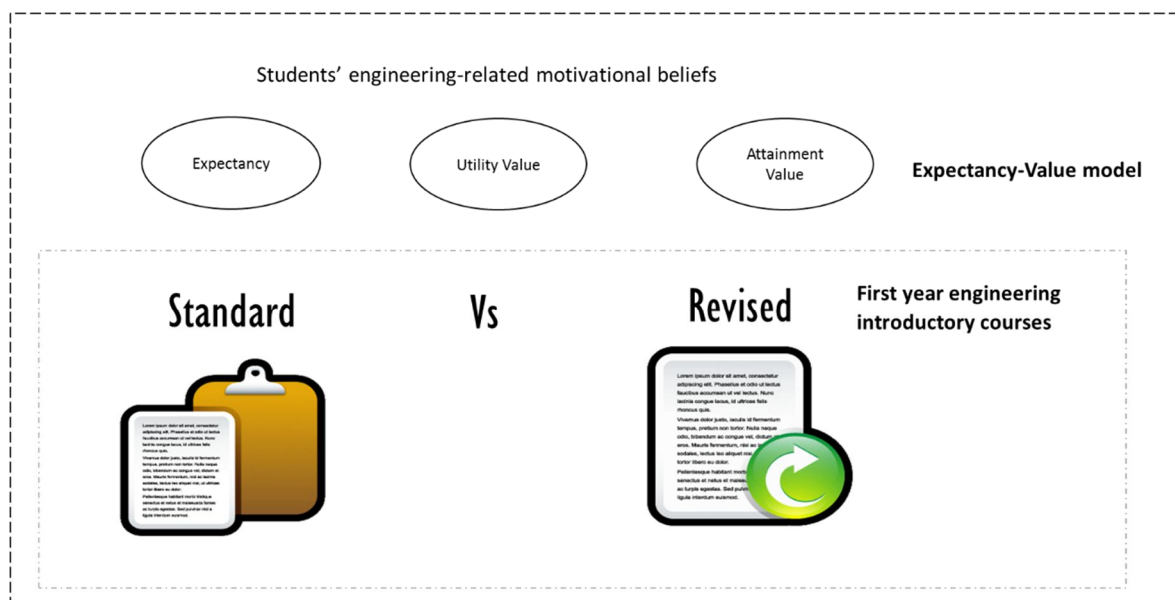


Figure 5. Representation of the Variables in this Study (Manuscript 2).

Framework: Expectancy-Value Theory

Expectancy-Value theory (Eccles, 1983; Wigfield & Eccles, 1992, 2000) is based on the expectancy and value constructs from an earlier work by Atkinson (1966).

Atkinson concluded that expectancy and task-value beliefs are inversely related. Eccles and her colleagues disagreed with Atkinson and found that expectancy and task-values beliefs are positively related (Wigfield & Eccles, 1992). In addition, and in contrast to Atkinson model, the theory developed by Eccles and her colleagues “focuses on the social-psychological reasons for people’s choices in achievement settings; thus, expectancy and values are defined as cognitive rather than purely motivational constructs” (Wigfield & Eccles, 1992, p. 14). In the *Handbook of Competence and Motivation* (Elliot, Elliot, & Dweck, 2005) it is evident that several current research studies in educational settings are using motivation theories, because of the cognitive aspect that these theories include.

The Expectancy-Value model theorizes that an individual’s performance,

persistence, and task choice are all shaped by both his/her Expectancy for success and values (Wigfield & Eccles, 2000). From an individual's point of view, expectancy beliefs describe the *ability* to do the task, whereas task-values clarify the *importance* of a task (Wigfield, Byrnes, & Eccles, 2006). Eccles, et al., have tested this theory empirically, and have found that students' expectancies for success are strongly related to their performance on a given task, whereas students task values predict school course planning and enrollment decisions even after controlling for prior performance levels (Eccles, 1983; Meece et al., 1990).

Theoretical evidence suggests that expectancies for success are similar to Bandura's (1997) self-efficacy theory, since they share similar constructs, such as individual perceptions of their abilities to succeed in a task (Meece et al., 1990). Task-value beliefs refer to the desire to engage, or the importance to engage, in an activity. Value beliefs consist of four elements: Interest, Importance or Attainment, Utility, and Cost (Wigfield & Eccles, 2000). These four elements describe how individuals assign importance to engage in an activity (Eccles, 2005).

Many contributing factors shape Expectancy-Value beliefs. According to this model, social elements such as cultural milieu, socializers, identity characteristics, and experiences are related to cognitive processes, including perceptions of social environment and interpretations of past events. These cognitive processes are, in turn, related to goals, general self-schemas, and affective reactions. Furthermore, these goals and general self-schema beliefs contribute to an individuals' expectation for success and subjective task value. These motivational beliefs are directly related to an individuals' choice of persistence, quantity of effort, cognitive engagement, and actual performance

(Eccles, 2005). Figure 6 shows the more recent version of the Expectancy-Value model formulated by Eccles and her colleagues. For this study, I focused specifically on the Expectancy-Value motivational beliefs shown in gray shading in the figure 6.

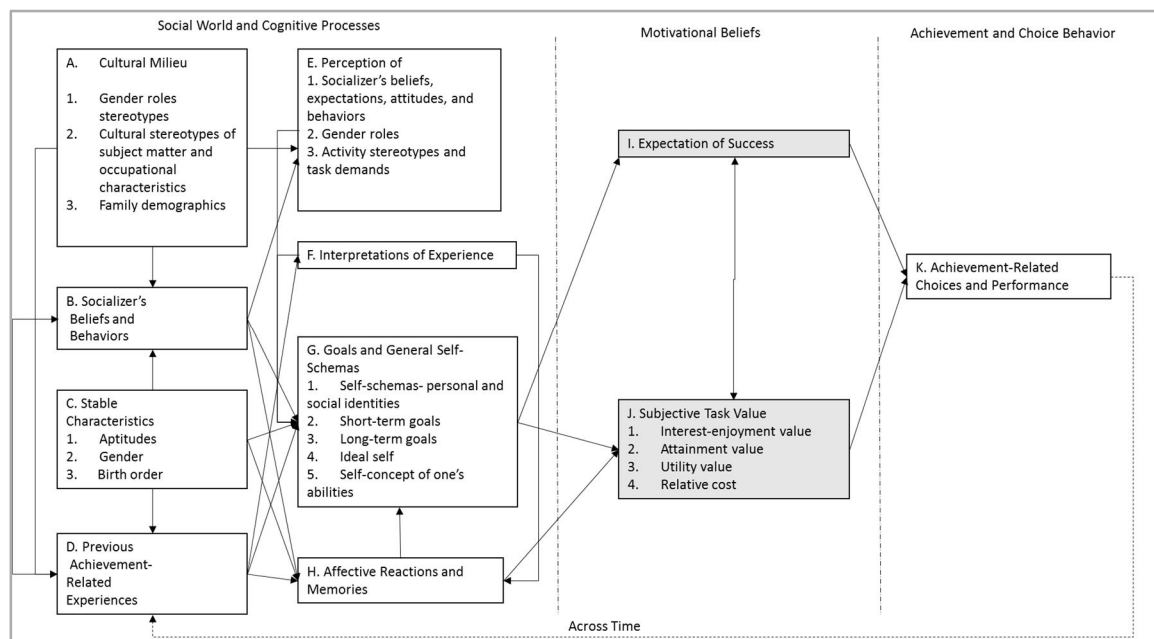


Figure 6. Expectancy-Value Model of Achievement-Related Choices. Eccles and Wigfield (2002).

Expectancy beliefs.

The *Expectancy* part of the model refers to individuals' beliefs about how well they will do on a task (Eccles & Wigfield, 2002). Theoretical evidence suggests that expectancies for success are similar to Bandura's (1997) Self-Efficacy theory since they share similar constructs, such as individual perceptions of their abilities to succeed in a task determine their task performance (Meece et al., 1990).

Task-value beliefs.

Task-value beliefs refer to the desire to engage or the perceived importance to

engage in an activity. Value beliefs consist of four elements: Interest, Importance or Attainment, Utility, and Cost.

Interest-enjoyment or intrinsic value refers to the satisfaction that results from performing a task. There is evidence that intrinsic value predicts academic engagement and learning (Wigfield & Eccles, 2000).

Attainment refers to the value an individual attaches to participating in a task or the personal importance of doing well on the task (Wigfield & Eccles, 2000).

Utility value refers to how useful or how well a required task is related to individual's current or future goals.

Cost refers to any negative exchange that takes place in engaging in the task, or the amount of effort necessary to succeed, as well as lost benefits that may result from an individual's choice (Wigfield & Eccles, 2000).

Eccles and her colleagues have been studying the psychological and social factors associated with academic course enrollment decisions, college major selection, and career choices for more than 45 years. Empirical support for the links established in the Eccles' model have been most focused on pre-college students. Results from some of these studies show that even when the level of previous performance is controlled, students' competency beliefs strongly predict their performance in different domains, whereas students' subject task value predict both intentions and actual decisions to engage in activities (Meece et al., 1990; Nagy, Trautwein, Baumert, Köller, & Garrett, 2006; Wigfield, Eccles, Schiefele, Roeser, & Davis-Kean, 2007). Both competence and value beliefs generally decrease with age (Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002; Luttrell et al., 2009; Wigfield, 1994). In addition, changes in competence beliefs

accounted for an associated decline in task values (Jacobs et al., 2002); the combination of both high-self concepts and values suggests both as important to increase the likelihood of persevering and pursuing a career (Simpkins, Davis-Kean, & Eccles, 2006). In a like manner, there is a strong relation between early (as youngsters) psychological and socio-cultural factors, and later (as young adults) aspirations due, in part, to the influence on an individual's development of expectancies and values regarding his/her chosen field of study (Zarrett & Eccles, 2006). In the same way, some studies have shown that youth's mathematics and science activity participation predicted their Expectancy and value beliefs (Simpkins et al., 2006).

Significantly, the Expectancy-Value model presents a framework to explain students' choices of different activities and their persistence at those activities (Bøe, Henriksen, Lyons, & Schreiner, 2011; Chow, Eccles, & Salmela-Aro, 2012; Eccles & Barber, 1999; Luttrell et al., 2009; Simpkins et al., 2006; Wigfield & Eccles, 1992). Based on their experiences, individuals judge how well they expect to do on a task, as well as how much they value their success on such a task (Wigfield & Eccles, 1992). Specifically, perceived importance, or Utility, rather than self-concept of ability has been found to be the stronger predictor of activity choices. This pattern has been especially true in the academic domain (Eccles, Wigfield, & Schiefele, 1998). However, students often consider tasks related to mathematics and science as important in general, but less important for them personally (Bøe et al., 2011).

Further, task values beliefs appear to be a more precise predictor of activity choice than Expectancy beliefs (Wigfield & Eccles, 2000). For example, Meece examined the relative influence of mathematics performance, self-perception, and affect

variables such as performance expectancies and value perceptions, on students' subsequent grades and course enrollment intentions in mathematics. Meece et al. found that students' performance expectancies predicted subsequent mathematics grades, whereas their value perceptions predicted course enrollment intentions (Meece et al., 1990).

In terms of gender, it is noted that male and female demographics affect behavioral choices through an influence on identity formation, which, in turn, shapes expectations and values (Eccles & Barber, 1999). For example, females were found to be less likely than males to go into engineering and the physical sciences, primarily because females felt these professions do not directly help people. This value placed on the type of job predicted women's decisions of not going into the physical sciences and engineering professions (Wigfield et al., 2007).

Research has also suggested that school interventions should better match early adolescents' developing characteristics, in order that any decline in adolescents' achievement and value beliefs will decrease (Wigfield, 1994). Researchers have also highlighted the influence and input of socializers such as parents, teachers, and peers on students' expectancy and values. All these factors are considered important, and are suggested as a focal point for promoting youth to pursue science. Therefore, interventions focused on such issues as stressing the importance of early encouragement of children's interest and confidence in mathematics and technical/physical science were suggested because of their later influence on occupational choices (Zarrett & Eccles, 2006). Equally important, researchers have suggested that future research assess how students' values are affected by instruction, and what those values might advocate for

regarding the structure of effective curricula at institutions of higher learning (Luttrell et al., 2009).

Expectancy-Value beliefs have not been studied widely in STEM (Science, Technology, Engineering, and Math) fields at the college level. One of the exceptions is a study by Perez, Cromley, and Kaplan (2014) which investigated the role of college students' identity development and motivational beliefs in predicting their chemistry achievement, or lack thereof, and resulting intentions to abandon STEM majors. The results of the analysis showed that competence beliefs, values, and perception of costs for the declared majors were related to both students' achievement and intentions to leave the STEM major (Perez et al., 2014).

In engineering, some studies have showed optimistic results in examining Expectancy-Value beliefs to have a better understanding of persistence and activity choice. For example, the work by Li et al. (2008) suggests an explanation to attrition in engineering schools in the U.S. Li, et al. found that, in general, college students agree that engineering is beneficial to society but they tend to believe that it takes too much effort to earn an engineering degree, and they do not feel that studying engineering is particularly interesting (Li et al., 2008). Similarly, Matusovich, Streveler, and Miller (2010) asserted that different patterns exist in the types of value students assign to earning an engineering degree. They concluded that values are very important in students' choices to become engineers and furthermore highlighted the importance of examining students' values beliefs in order to contribute to efforts to increase persistence in engineering colleges (Matusovich et al., 2010). These few examples of the study of Expectancy-Value beliefs in engineering students suggest that students' Expectancy-Value beliefs can help to

increment our understanding of persistence.

Specifically with first year engineering students, Jones et al. (2010) examined the relationships among Expectancy-Value constructs and achievement and career plans. They concluded that value constructs predicted career plans better than expectancy constructs for both males and females. They found that expectancy and value constructs predicted different outcomes: expectancy constructs predicted achievement, whereas value constructs predicted career plans. In addition, Jones et al. found that students value beliefs decreased over the first year for both male and female students (Jones et al., 2010).

One more recent study including first-year engineering students is the one by McGrath et al. (2013). They used Expectancy-value theory to study how first-year engineering students, including both those who persist in engineering and those who switch to different majors, perceive engineering. Using interview data from 11 students who stayed in engineering and 10 who switched to a different major, McGrath et. al found that while both expectancy and value beliefs were indicators for decisions about persisting or switching, value beliefs were the best predictor of students' decisions (2013).

As can be seen among motivational frameworks, Expectancy-Value beliefs have been hypothesized as an adequate predictor of students' activities choices and persistence. In order to design more effective educational courses and classroom practices that contribute to improving, or at least mitigating, a decline in students' expectancy value beliefs, we need a better understanding about what these students' motivational beliefs endorse regarding the structure of courses and classroom practices in

engineering. Eccles' model presents a unique framework to help with this purpose.

Methods

This section describes measures of motivational beliefs of two groups of students enrolled in two versions of an introductory engineering course. Specifically, this study explores students' Expectancy-Value engineering-related motivational beliefs.

Engineering-related motivational beliefs are broad views about the engineering domain, such as conviction about becoming, or pursuing a career as, an engineer. I used existing data that includes items representatives of the constructs involved in the Expectancy-Value model. The purpose of this manuscript is to determine whether there are statistically significant differences in students' Expectancy-Value engineering-related beliefs between two groups of students: students who enrolled in the *standard* course and those who enrolled in the *revised* version of the introductory engineering course. These differences have been analyzed at the beginning and at the end of the semester. In addition, changes in students' motivational beliefs across the semester have been analyzed for both groups.

This section will describe the methods by which data was collected, and the analytical methods that were used to test for differences between the two groups of students. Data from the beginning of the semester (BOS) and end of the semester (EOS) "Motivational Beliefs" surveys allow for comparisons of the two groups of students' motivational beliefs at the beginning, at the end, and throughout the semester. Results from this analysis provide insight into if course type has a significant influence on both students' motivational beliefs at the end of the semester, as well as potential variations in students' motivational beliefs from the beginning to the end of the semester. It is

important to highlight that this study does not address hypothesis testing of the effects (causality) of the introductory engineering course on students' Expectancy-Value beliefs. According to the Eccles' model, many contributing factors shape Expectancy-Values beliefs: past experiences, socializers, and identity characteristics that have not been included in the analysis in this study

Institutional review board.

A research application form was submitted to the Institutional Review Board at the University for this study. In order to protect the identities and privacy of the students included in the study, the participants were assigned an anonymized, unique ID, preventing the students from being identified. The Institutional Review Board reviewed the application and authorized the use of student records for this study.

Data collection.

This study used data previously collected by the engineering department where the two versions of the introductory engineering courses were offered. Secondary data analysis is the use of existing data to investigate research questions others than those for which data were originally collected (Vartanian, 2010, p.3). The main advantages of using existing data are promptness and economy. In addition, the existing data was collected from a population that is ideal for the purpose of this study. The existing data were used as measures of students' motivational beliefs in each of the courses included in this study, which allows for comparisons between the two groups of students. Data used for this study had been collected through the "Motivational Expectancy-Value Beliefs" survey conducted at the beginning and at the end of the semester where both versions of the course were offered.

The instrument.

The purpose of this study is descriptive; its aim is to compare students' motivational beliefs at the beginning, at the end, and throughout the semester in the two versions of the introductory engineering course. The data used in this study include items that are representatives of the constructs involved in the Expectancy-Value model. These items have been used to measure specific constructs related to engineering motivational beliefs e.g. (Jones et al., 2014; Jones et al., 2010; Jones et al., 2016). For the current study, I selected the constructs that represent well the Expectancy-Value model. All the items were rated using a 6-point Likert-type scale ranging from *strongly disagree*= 1 to *strongly agree*=6. The survey instructions for this study include an explicit statement as follows: 1) "When asked about engineering-related courses, please refer to your math, science, and engineering courses", and 2) "In answering, please think about engineering as a field, not as any one particular course". These instructions were included in order that participants would not limit their responses to the introductory engineering courses required for all engineering students (Jones et al., 2010). The constructs included in this study are presented in the sections that follow.

- 1) **Expectancy for success in Engineering:** This construct was measured by using five items. The items in this construct have been used with first year engineering students to assess their Expectancy for success in engineering (i.e Jones et al., 2010). These items were based on scales used by Eccles and Wigfield (1995) to assess students' expectancies in academic domains (Jones et al., 2010). A sample item of this construct is, "Compared to other engineering students, I expect to do well in my engineering-related courses this year."

- 2) Attainment value: This construct was measured using four items. The items in this construct have been used with first year engineering students to assess their identification with engineering (i.e Jones et al., 2010). These items were based on scales developed by Schmader, Major, and Gramzow (2001) to measure the extent to which undergraduate students devaluated academics. Engineering Attainment or importance value and identification with engineering have been found to be very close-related constructs (Jones et al., 2010). (Jones et al., 2010). A sample item of this construct is, “Being good at engineering is an important part of who I am.”
- 3) Utility value: This construct was measured using six items. The items in this construct have been used with first year engineering students to assess their engineering Utility value (i. e Jones et al., 2014; Jones et al., 2016). These items were based on scales developed by Luttrell et al. (2010). (Jones et al., 2010). The items included in the survey for this construct were negatively worded, therefore these items were reverse coded during data analysis. A sample item of this construct is, “Knowing about engineering does not benefit me at all.”

The other two value-related constructs, Interest and Cost value, are not included in the analysis of this study. Interest value was not included in the existing dataset and Cost value was represented by only one item.

Students were invited to complete the questionnaire including items representing the three constructs included in this study: Expectancy, Attainment, and Utility value, along with other demographic questions, additional motivational constructs, and further questions about the course content and outcomes. Participants completed the survey

twice during the semester: at the beginning of the semester, specifically during the second week, and again at the end of the semester, during the last three weeks of the course. An initial email, as well as two reminders, were sent with a link to the online questionnaire. The completion of the questionnaire counted as a homework assignment; however, students were informed that instructors would not have access to the individual answers they provided.

Validity and reliability.

Jones et al. (2010) discussed the validity and reliability of some of the items included in this survey. They stated that since some of the constructs had not been used with first year engineering students, they established the validity of the constructs for this population. Content validity was ensured by two experts in engineering education who read all the items and validated that the questions were appropriate for first-year engineering students. Jones, et al. revised some items based on experts' suggestions. They also asked first-year engineering students who did not participate in the study to rate each of the scale items. Jones et al. (2010) did not ask students to answer the questions, but rather to rate the wording of each item in terms of clarity, ensuring students would understand what was being asked, and that the item actually made sense. Subsequently, they revised the items that were not clear according to students' recommendations.

After data collection, Jones et al. (2010) estimated the internal consistency reliability of the scales by calculating Cronbach's alpha. They used criteria based on suggestions by George and Mallery (2003): greater than 0.9 was excellent, between 0.8 and 0.9 was good, between 0.7 and 0.8 was acceptable, between 0.6 and 0.7 was

questionable, between 0.5 and 0.6 was poor, and below 0.5 was unacceptable. Jones et al. obtained good internal consistency coefficient for expectation for success ($\alpha = 0.82$ for instrument 1 and $\alpha = 0.81$ for instrument 2), acceptable for the engineering Attainment ($\alpha = 0.64$ for instrument 1 and $\alpha = 0.71$ for instrument 2), and unacceptable for Utility value ($\alpha = 0.36$ for instrument 1 and $\alpha = 0.43$ for instrument 2). The authors of this study speculated that first-year engineering students may not understand how theoretical courses are useful in their daily life; due to this reliability problem they used only one item of this scale asking students how useful learning engineering was for what for what they wanted to do after they graduate (Jones, et al., 2010, p. 324).

While the reliability and validity of this instrument in previous research contribute to the current validity and reliability of the survey, additional tests should be run to ensure the reliability and validity of the specific instrument to be used for the study and in this context (Nunnally, 1978). I examined construct validity. Some researchers consider that this type of validity includes all categories of validity (Messick, 1993). In other words, they state that construct validity can be examined for how it is linked to other sources of validity evidence. I conducted an exploratory factor analysis (EFA) to identify underlying factor structure, and if irrelevant items did not fit into any existing factors, then a CFA was conducted to confirm or refine the factor structure previously identified through EFA. In terms of internal reliability of the survey, Cronbach's alpha was calculated. Criteria by George and Mallery (2003) suggest that a value greater than 0.9 is excellent, between 0.8 and 0.9 is good, between 0.7 and 0.8 is acceptable, between 0.6 and 0.7 is questionable, between 0.5 and 0.6 is poor, and below 0.5 unacceptable (2003). It is necessary to use these general guidelines with caution because the value of the

Cronbach's alpha coefficient depends on the number of items in a construct (Field, 2009). For this reason, the Spearman-Brown formula was used in cases where a construct has less than 10 items in a construct since Cronbach's alpha is sensitive to number of items in a construct (Alsawalmeh & Feldt, 1999). That is to say, tests of fewer than ten items are unlikely to be reliable. Spearman-Brown formula is a correcting formula that compensate this in constructs with less than ten items (Kline, 2013).

Participants and setting.

The participants in this study are general first year engineering students from the same cohort enrolled in either the standard or the revised version of a required introductory course at a large, public university in the mid-Atlantic United States. The engineering program included in this study fits into the taxonomy of engineering matriculation practices, developed by Chen and colleagues (2013), as an FYE program. Students are admitted to the college of engineering as general engineering students, and are required to take an introduction to engineering sequence during the first year. In addition to first year introductory courses, this institution counts on a general academic advising, and a living learning community as part of the structure of its first-year program.

Students were randomly placed into one of the two versions of the course at the beginning of the semester. All students were emailed asking them to complete the survey. Tables 11 and 12 show participant demographics for BOS and EOS respectively.

Table 11.

Participant Demographics Motivational Beliefs Survey (BOS)

Gender	Standard	Revised
Female	23% (197)	14% (26)
Male	76% (642)	86% (160)
No Reported	1% (12)	0
Total	851	186

Table 12.

Participant Demographics Motivational Beliefs Survey (EOS)

Gender	Standard	Revised
Female	23% (188)	15% (36)
Male	76% (620)	85% (204)
No Reported	1% (4)	0
Total	812	240

Data analysis.

Descriptive statistics were analyzed to better understand data distribution and frequencies of the variables in the study. The average of the items for each construct represents the means scores reported in this study. Means have been compared between the two groups of students and among the same group across the semester.

Variables.

The independent variable, Course Type, represents which course type each student is enrolled in, either in the standard or the revised version. This variable was represented as a binary variable, with 0=standard and 1=revised. The variables Expectancy, Attainment, and Utility represent the examination of students' engineering-

related Expectancy-Value beliefs. These motivational beliefs are measured at the engineering domain level.

Statistical tests.

I examined the possible statistically significant differences in students' engineering-related motivational beliefs between two groups of students: students enrolled in the standard version and students enrolled in the revised version of an introductory engineering course. This was done by conducting the nonparametric equivalent to t-tests to analyze data collected through surveys filled out by students at both the beginning and the end of the semester. The reason for using the nonparametric tests was because the data were non- normally distributed. Data were analyzed using SPSS 24.0 software.

Two Mann-Whitney U tests, which is the equivalent to an independent t-tests for non-normal data, were performed, one with the dataset at the beginning of the semester (BOS) and one with the dataset at the end of the semester (EOS), to determine if there were statistically significant differences in students' engineering-related motivational beliefs for students in the standard version versus those in the revised version of the course. Mann-Whitney U tests is a rank-based test used to look for statistically significant differences between two different groups (Field, 2009). In addition, two Wilcoxon signed-rank tests were conducted tracking each group of students from the beginning to the end of the semester examining changes in their motivational beliefs over the duration of a semester. Wilcoxon signed-rank test is the equivalent to a dependent, or paired, T-test which is used when differences between scores from the same participants are analyzed (Field, 2009). Effect sizes were also calculated to demonstrate “the

importance” of any differences since statistical significance can be affected by sample sizes (Cohen, 1988, Rosnow & Rosenthal, 1996). Originally, ranges for effect sizes were defined as small: $d=0.2$, medium, $d= 0.5$; and large, $d=0.8$ (Cohen, 1988). However, a meta-analysis study developed simultaneously with Cohen’s work suggested to adjust ranges of effect size as they applied to social science research as: near zero $d \leq 0.10$; small $0.11 < d \leq 0.35$; moderate $0.36 < d \leq 0.65$; large $0.66 < d \leq 1.0$; and very large $d > 1.0$ Hyde (1985). The overarching research question for this study is: How do students’ Expectancy-Value engineering-related beliefs differ between students enrolled in the standard versus the revised versions of a first-year introductory engineering course? Specific research questions are as follows in Table 13.

Table 13.
Specific Research Questions (Manuscript 2)

<i>Research questions</i>	<i>Test Type</i>
RQ 2. 1. Is there a significant difference in students' Expectancy-Value engineering-related beliefs between students enrolled in the <i>standard</i> and <i>revised</i> versions of a first-year introductory engineering course at the beginning of the semester?	Mann-Whitney U test
RQ 2.2. Is there a significant difference in students' Expectancy-Value engineering-related beliefs between students enrolled in the <i>standard</i> and <i>revised</i> versions of a first-year introductory engineering course at the end of the semester?	Mann-Whitney U test
RQ 2.3. Is there a significant difference in students' Expectancy-Value engineering-related beliefs among students enrolled in the <i>standard</i> version of a first-year introductory engineering course between the beginning and the end of the semester?	Wilcoxon signed-rank
RQ 2.4. Is there a significant difference in students' Expectancy-Value engineering-related beliefs among students enrolled in the <i>revised</i> version of a first-year introductory engineering course between the beginning and the end of the semester?	Wilcoxon signed-rank

Before conducting the tests, preliminary analysis was performed, including: 1) Levene's test for equality of variances which measures how far the data set is spread out in the two groups of students and 2) Shapiro-Wilk test of normality. Results of this preliminary analysis were used to determine whether the tests should assume equal or unequal variances, as well as normal or no-normal data distribution. Since the data were

non-normally distributed, nonparametric tests were used.

Results

Construct validity.

Exploratory factor analysis

I conducted a principal component analysis (PCA) in SPSS on the 15 items included in the Motivational Beliefs survey to determine if all the motivational beliefs items loaded onto their respective factors; this was the case for all of the items. Orthogonal rotation (varimax) was used. Varimax rotation attempts to maximize the dispersion of loadings within factors (Field, 2009). The Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis, KMO= 0.883 and all the KMO values for individual items were >0.82, which is well above the acceptable limit of 0.5 (Field, 2009). Barlett's test of sphericity $\chi^2 (120) = 157885.729$, $p < 0.001$ was significant indicating that there are some relationships between the variables included in the analysis, and therefore PCA analysis is appropriate. I run an initial analysis to obtain eigenvalues for each component in the data. Three components had eigenvalues over Kaiser's criterion of 1 and in combination explained 66.11% of the variance, with factor 1 contributing 37.45%, factor 2 contributing 17.60%, and factor 3 11.05%. The pattern matrix is shown in Table 14. Overall, the results suggest that all the factors had the highest loading on the factor with the other items in the same subscale. All of the engineering Utility items (B5-B10) loaded highest on factor 1, all of the engineering expectation items (D1-D5) loaded highest on factor 2, and all of the Attainment items (B1-B4) loaded highest on factor 3.

Table 14.
Factors Loading from the EFA- Motivational Beliefs Items

	<i>Factors</i>		
	<i>1</i>	<i>2</i>	<i>3</i>
B8	.88		
B6	.85		
B7	.83		
B9	.80		
B5	.77		
B10	.65		
D2		.83	
D4		.82	
D5		.81	
D1		.80	
D3		.76	
B3			.86
B2			.83
B4			.82
B1			.61

Note: Only highest coefficients are shown for each item (all loadings > 0.5).

Results of the EFA showed that all of the motivational beliefs items loaded cleanly onto three different factors. This is, the three sets of Motivational Beliefs items best explained their respective factors when grouped together. Factors loadings shows the relative contribution that an item makes to a factor/construct.

Confirmatory factor analysis

I conducted a CFA using AMOS version 24 to compute several indices used to measure the model-data fit. Kline (2005) suggests the four following judgments of fit associated with the CFAs: (a) the model chi-square statistic, (b) the comparative fit index (CFI), (c) the standardized root mean square residual (SRMR), and (d) the root mean square error of approximation (RMSEA). These indices can vary between 0 and 1; higher values for the CFI indicate better fit while that lower values for the SRMR and the RMSEA indicate a better fit. All the latent variables (Utility, Expectancy, and Attainment) were allowed to covary. In addition, according to the modification indices in the model, two Expectancy and two Attainment items were allowed to covary. The resulting fit indices were as follows: SRMR= 0.06, RMSEA= .05, and CFI= .98. These scores indicate a good fit between the model and the observed data (R. Kline, 2005). Figure 7 shows the final model. These results confirm the explorative identified factors in the EFA.

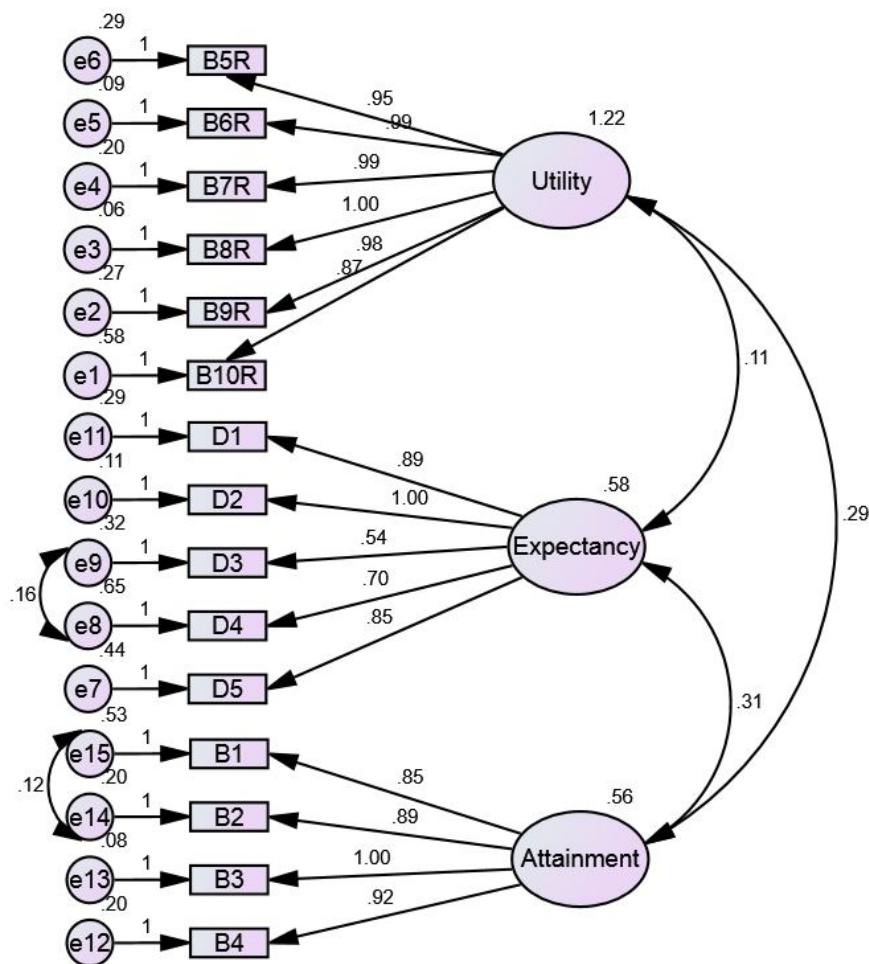


Figure 7. Confirmatory Factor Analysis for Motivational Expectancy-Value Beliefs.

The model provided a good fit to the data as indicated by the model fit indices supporting the hypothesis that the three factors that are part of the Expectancy-Value model are theoretically distinct constructs. No post-hoc modifications were performed because of the good-fit indexes.

Reliability.

All the Motivational Beliefs construct showed acceptable Cronbach's alpha values for each course type. Results are shown in Table 15. All Cronbach's coefficients resulted >0.7 indicating stability of the scales. In all the cases, the Spearman-Brown

formula was used to assess reliability values since all the scales had fewer than 10 items (Alsawalmeh & Feldt, 1999).

Table 15.
Motivational Constructs, Corresponding Number of Items and Internal Reliability Coefficient for Each Course.

<i>Construct</i>	<i>N of Items</i>	<i>Cronbach's Alpha</i>	<i>Course Type</i>
		0.76	BOS Standard
Attainment	4	0.82	EOS Standard
		0.82	BOS Revised
		0.84	EOS Revised
		0.88	BOS Standard
Utility	6	0.94	EOS Standard
		0.91	BOS Revised
		0.96	EOS Revised
		0.85	BOS Standard
Expectancy	5	0.89	EOS Standard
		0.81	BOS Revised
		0.90	EOS Revised

Note: [BOS = Beginning of Semester / EOS = End of Semester]

Statistical tests.

Before conducting the T-test, preliminary analysis was performed, including: 1) Levene's test for equality of variances which measures how far the data set is spread out in the two groups of students, and 2) Shapiro-Wilk test of normality. Results of this preliminary analysis indicated that the assumption of homogeneity of variance could be assumed and that the data were non-normal distributed, therefore non-parametric tests were conducted.

The overarching research question for this study is: How do students' Expectancy-Value engineering-related beliefs differ between students enrolled in the standard versus revised versions of a first-year introductory engineering course? To answer this question, the following sub questions were examined:

RQ 2. 1. Is there a significant difference in students' Expectancy-Value engineering-related beliefs between students enrolled in the standard and revised versions of a first-year introductory engineering course at the beginning of the semester?

I conducted an independent t-test to compare the motivational scores between students in *standard and revised versions* of the course at the beginning of the semester. Because the data was not normally distributed, a Mann-Whitney test was conducted. Results of the t-test are presented in Table 16, p-values less than 0.05 are considered statistically significant. Effect sizes were also calculated to demonstrate the *importance* of any differences since statistical significance can be affected by larger sample sizes (Cohen, 1988; Rosnow & Rosenthal, 1996). The Mann-Whitney test indicated *that there was no significant difference in the motivational constructs between the populations of students in the two versions of the course at the beginning of the semester.*

Table 16.

Comparison of Motivational Constructs at the Beginning of the First Semester of the Revised Course Implementation (Fall 2013).

<i>Course</i>	<i>N</i>	<i>Construct</i>	<i>Mean (SD)</i>	<i>Mdn</i>	<i>Z</i>	<i>P-value (2-tailed)</i>	<i>Effect Size</i>
Standard BOS	851	Attainment	5.25 (0.65)	5.25	-0.88	0.38	0.07
Revised BOS	184		5.20(0.66)	5.26			
Standard BOS	851	Utility	5.49 (0.67)	5.66	-1.65	0.09	0.19
Revised BOS	184		5.34 (0.90)	5.66			
Standard BOS	851	Expectancy	4.84 (0.68)	4.80	-.150	0.13	0.11
Revised BOS	183		4.92 (0.65)	5.00			

RQ 2.2. Is there a significant difference in students' Expectancy-Value engineering-related beliefs between students enrolled in the standard and revised versions of a first-year introductory engineering course at the end of the semester?

Similarly, I conducted an independent t-test to compare the motivational scores between students in the *standard and revised versions* of the course at the end of the semester. Because the data was not normally distributed, a Mann-Whitney test was conducted. Results of the t-test are presented in Table 17, p-values less than 0.05 are considered statistically significant. Effect sizes were also calculated to demonstrate the *importance* of any differences since statistical significance can be affected by larger sample sizes. The Mann-Whitney test indicated that *there was no significant difference in the motivational constructs between the population of students in the two versions of the course at the end of the semester.*

Table 17.

Comparison of Motivational Constructs at the End of the First Semester of the Revised Course Implementation

<i>Course</i>	<i>N</i>	<i>Construct</i>	<i>M (SD)</i>	<i>Mdn</i>	<i>Z</i>	<i>P-value (2-tailed)</i>	<i>Effect Size</i>
Standard EOS	810	Attainment	5.19 (0.74)	5.25	-0.73	0.46	0.04
Revised EOS	240		5.22 (0.74)	5.25			
Standard EOS	810	Utility	5.27 (0.96)	5.66	-0.13	0.90	0.03
Revised EOS	240		5.24 (1.08)	5.67			
Standard EOS	809	Expectancy	4.71 (0.77)	4.80	-1.80	0.07	0.15
Revised EOS	240		4.82 (0.68)	4.84			

RQ 2.3. Is there a significant difference in students' Expectancy-Value engineering-related beliefs among students enrolled in the standard version of a first-year introductory engineering course between the beginning and the end of the semester?

I conducted a dependent t-test to compare the students' motivational scores in the standard version of the course at the beginning versus the end of the semester. Because the data was not normally distributed, a Wilcoxon Signed-ranks test was conducted. The difference scores were symmetrically distributed, as assessed by a histogram. Results of the t-test are presented in Table 18, p-values less than 0.05 are considered statistically significant. Effect sizes were also calculated to demonstrate the importance of any differences since statistical significance can be affected by larger sample sizes. The Wilcoxon signed-rank test determined that *there were statistically significant differences in the motivational scores when comparing beginning and end of the semester*. All three

motivational constructs decreased by the end of the semester. This result is consistent with existing literature that shows that students' expectancy and value engineering-related beliefs decrease over the first year in an engineering program (Jones, et al., 2010).

Table 18.

Comparison of Motivational Constructs Across the Semester for the Standard course

<i>Course</i>	<i>N</i>	<i>Construct</i>	<i>M (SD)</i>	<i>Mdn</i>	<i>Z</i>	<i>P-value (2-tailed)</i>	<i>Effect Size</i>
BOS Standard	796	Attainment	5.24 (0.65)	5.25	-2.40	0.016*	0.10
EOS Standard	796		5.18 (0.78)	5.25			
BOS Standard	796	Utility	5.50 (0.64)	5.83	-6.36	<0.001*	0.27
EOS Standard	796		5.28 (0.96)	5.66			
BOS Standard	796	Expectancy	4.84 (0.67)	4.80	-4.88	<0.001*	0.19
EOS Standard	796		4.70 (0.83)	4.80			

Note: * $p < 0.05$ indicating statistical significant difference

RQ 2.4. Is there a significant difference in students' Expectancy-Value engineering-related beliefs among students enrolled in the revised version of a first-year introductory engineering course between the beginning and the end of the semester?

I conducted a paired t-test to compare the students' motivational scores in the standard version of the course at the beginning versus the end of the semester. Because the data was not normally distributed, a Wilcoxon Signed-ranks test was conducted. The difference scores were symmetrically distributed, as assessed by a histogram. Results of the t-test are presented in Table 19, p-values less than 0.05 are considered significant.

Effect sizes were also calculated to demonstrate the importance of any differences since

statistical significance can be affected by larger sample sizes. The Wilcoxon signed-rank test determined that *there were no statistically significant differences in the motivational scores when comparing beginning and end of the semester.*

Table 19.

Comparison of Motivational Constructs Across the Semester for the Revised Course

<i>Population (Course)</i>	<i>N</i>	<i>Construct</i>	<i>M (SD)</i>	<i>Mdn</i>	<i>Z</i>	<i>P-value (2-tailed)</i>	<i>Effect Size</i>
BOS Revised	168	Attainment	5.17 (0.67)	5.25	-1.19	0.23	0.09
EOS Revised	168		5.24 (0.74)	5.25			
BOS Revised	168	Utility	5.30 (0.93)	5.66	-4.12	0.68	0.05
EOS Revised	168		5.25 (1.08)	5.66			
BOS Revised	167	Expectancy	4.90 (0.64)	5.00	-1.53	0.12	0.12
EOS Revised	167		4.89 (0.70)	5.00			

Discussion

The results of the EFA and CFA provide construct validity evidence for the use of the scales with first year engineering students. The finding of strong loading factors indicates that the “Motivational Beliefs” survey offers a good measure of students’ engineering-related motivational beliefs. These scales could be used to measure students’ motivation to persist in engineering.

To compare the motivational constructs in the two version of the courses, I first compared data using a rank-based nonparametric tests at the beginning and at the end of the semester. The Mann-Whitney U test is often presented as the nonparametric

alternative to the independent-samples t-test, which can be used when that data is non-normally distributed. In general, there was no significant difference in the motivational constructs between the two versions of the course either at the beginning or at the end of the semester. These results build support for the notion that there are a variety of background factors that influence identification with a determined domain (Osborne & Jones, 2011), Expectancy and Utility values (Eccles & Wigfield, 2002). These factors include race/ethnicity, gender, social class, family demographics, and several aspects of students' academic experiences. According to the Expectancy-Value model, several factors shape Expectancy-Values beliefs such as identity characteristics, cognitive processes including perceptions of social environment and interpretations of past events, and goals that contribute to an individuals' expectation for success and subjective task value. It is necessary to include other variables that influence motivational beliefs for a more complete analysis. Although as instructors and instructional designers we cannot control for all the background factors that influence students' motivational beliefs, we have the opportunity to enhance the educational experiences part of the model by boosting students' positive perceptions of classes and classroom environments that support these beliefs, especially keeping in mind that these motivational beliefs are strongly related to student retention, goals, and career choice.

Additionally, I compared data from the beginning and the end of the semester for each version of the course using Wilcoxon signed-rank test. This test is used to determine whether there is a median difference between paired observations. This test is considered as the nonparametric equivalent to the paired-samples t-test. In the *standard* version of the course, the three motivational constructs: Expectancy, Attainment, and

Utility values were found to have declined significantly, which is consistent with existing literature e.g. Jones et al., (2010). In the *revised* version of the course, there were not statistically significant differences in the three constructs between the beginning and the end of the semester. This finding is important and must be interpreted according to its practical significance.

Attainment value refers to “the personal attached to doing well on a given task” (Eccles, 2005, p. 109). This construct is considered similar to domain identification which is defined the extent to which one defines the self through a role or performance in an determined domain (Osborne & Jones, 2011). Utility refers to the usefulness of engineering in terms of reaching one’s short and long-term goals and Expectancy refers to the student’s belief of their success in engineering (Eccles, 2005). The decline of these constructs in the standard version of the course replicates findings from prior studies that indicate that students’ engineering-related motivational beliefs decrease over the first year in an engineering program (Jones et al., 2010). The effect sizes for these changes are considered small. These effect sizes suggest that, even in the event of a statistically significant difference among construct values, the importance of the significance is small (Cohen, 1977). In other words, the significance may be enhanced by a large sample size. However, just like p-values, these general guidelines for effect sizes, such as small (<0.2), must be interpreted with caution. Rather findings from studies need to be interpreted by their practical significance (Kirk, 1996). In this study, the finding that in the *revised* version of the course, the motivational constructs did not change significantly by the end of the semester could be interpreted as an indicator that the new version of the course helps to mitigate drops in students’ motivational beliefs. Motivational beliefs are

affected by many factors that are impossible to control. However, the finding that there were not statistically significant differences for students' Expectancy-Value beliefs for this group of students encourages instructional designers and faculty to remain open-minded about possible improvement in course development in the future. As instructors and course developers, this is the perhaps the factor that influences students' motivational beliefs that we can control the most.

Since Expectancy, Attainment, and Utility values have been found to be predictors of major and career choice (Jones et al., 2016), results of studies including these motivational constructs could allow the early identification of students without some moderate level of engineering- related motivational beliefs. This early identification, however, is beneficial only if we can put in practice some strategies that can help to boost students' motivational beliefs. Some such strategies that can be implemented and that have proven effective in the design of instruction are those based on the MUSIC model of Academic Motivation (Jones, 2009). As instructors and instructional designers, we are in a unique position to implement these strategies informed by research that can have such impact on the future engineering workforce.

Conclusions and Future Work

This study sought to examine the possible differences and changes in constructs within motivation for first year students during the revision of a first-year curriculum. Although the motivational constructs did not present statistically significant differences between the two versions of the course, the identification of differences in motivational constructs between the beginning and the end of the semester in the standard course replicates findings from prior studies that indicate that students' motivation decreases

significantly over the first year in an engineering program. More notably, the finding that in the revised version of the course there were not statistically significant differences in the motivational constructs between the beginning and the end of the semester is promising. Additionally, results show that the “Motivational Beliefs” survey provides a useful tool that can be applied in foundational courses to reveal critical information about students’ motivation, attitudes, and beliefs about engineering and their intention to completing an engineering degree. This information is relevant as we strive to support engineering students’ success.

This analysis was limited to only one semester. Additional research is needed to measure changes in students’ motivation in the following semesters to assess whether the population of the pilot course is representative of the entire population of first-year engineering students. Future research could consider longitudinal analysis of students’ motivational beliefs. I recognize the limitation that the two versions of the course are not the only difference that can affect students’ motivation; instructors, for example, play a major role in motivating students by creating and fostering effective learning environments in the classroom, and the courses I compared had different instructors. Disaggregation of data by instructors as well as by subpopulation could provide valuable information about the variety of outcomes. Another limitation of this work is that the survey is applied only at two points during the semester, at the beginning and at the end; intermediate surveys could give more information about trajectories in students’ beliefs along the semester. In the same way, qualitative research could be beneficial since our data is reduced to numbers; therefore, students’ voices about their own motivation may not be adequately represented and could help to better understand the necessary revision

in curriculum and instruction.

Limitations

Results of this study rely on self-reported data for all the variables. Self-report data is generally considered to be subjective from person to person. However, many researchers have established that self-report data is a credible means of examining students' perceptions especially if the questions are about recent events (Kuh, 2005). This limitation was also minimized in this study by including "reverse" questions on the survey, so that positive and negative responses cancel out any response bias. An example of reverse item is: "Knowing about engineering does not benefit me at all."

The value constructs of the Expectancy-Value model consist of four elements: Interest, Attainment, Utility, and Cost. This study is based on data that had already been collected; the interest element was omitted in the data collection. Future studies should include items to measure this construct. However, as a result of an exploratory factor analysis conducted in a previous study including a sample of college students from several U.S universities, the items used for measuring Intrinsic value (Interest) and Attainment value were intertwined, indicating that it seems that interest in studying engineering and interest in working as an engineer (Attainment) can be combined together (Li, McCoach, Swaminathan, & Tang, 2008). This indicated that the Interest element seems to be very close to the Attainment element for engineering college students; which makes sense conceptually because Interest value refers to the enjoyment of engineering or engineering-related activities and Attainment value refers to the importance attached to a task such as pursuing an engineering-related career.

In addition, in this study the Cost element is measured with only one item in the

survey and was not included in the analysis. Despite its importance, this construct has been the least studied of the four components of subjective-task values (Wigfield, Tonks, & Klauda, 2009). Further research considering the inclusion of more items to better measure this construct is necessary but was outside of the scope of this study.

Chapter Four

Examining the Relationship Between the MUSIC Model of Academic Motivation Components and Expectancy-Value Beliefs

Introduction

Existing engineering education research has suggested that students' perceptions in introductory engineering classes might affect their motivational beliefs (Jones et al., 2014; Jones et al., 2016). Similarly, research has also indicated that students' engineering-related motivational beliefs predict their engineering career goals (Jones et al., 2016). This study is built on existing research with the purpose to extend those findings and to add to the understanding about how introductory engineering classes affect students' motivation to remain in the field of engineering. This study analyzed whether students' perceptions of two different versions of an engineering introductory course were related to their engineering-related motivational beliefs.

Included in this study are two frameworks from motivational research: 1) The MUSIC model of Academic Motivation (Jones, 2009), which serves to analyze students' perceptions of the courses, and 2) the Expectancy-Value model (Wigfield & Eccles, 2000), utilized to analyze students' motivational beliefs. Students' perceptions are understood to be beliefs about the learning environment in academic settings, such as a course or a class. Motivational beliefs, in turn, are broader views related to a specific domain, for example, the engineering domain, the focus of this study. I examined whether students' perceptions of an engineering introductory course predict their Expectancy-Value engineering-related beliefs. I sought to answer the following research question: *To what extent do first-year engineering students' perceptions, based on the*

MUSIC model components, in two versions of an introductory engineering course relate to their Expectancy-Value engineering-related beliefs? Figure 8. shows a representation of the variables in this study (manuscript 3).

Literature Review

The MUSIC Model.

I used the MUSIC model of Academic Motivation, developed by Jones (2009), to examine students' perceptions of the two versions of an engineering introductory course. The MUSIC model provides a useful set of components to measure students' perceptions of their academic settings. The acronym, MUSIC, refers to the five components included in the model: eMpowerment, Usefulness, Success, Interest, and Caring (Jones, 2009). Each of the five components are linked to a group of strategies that can be used to better support students' motivation in academic settings (Jones, 2009).

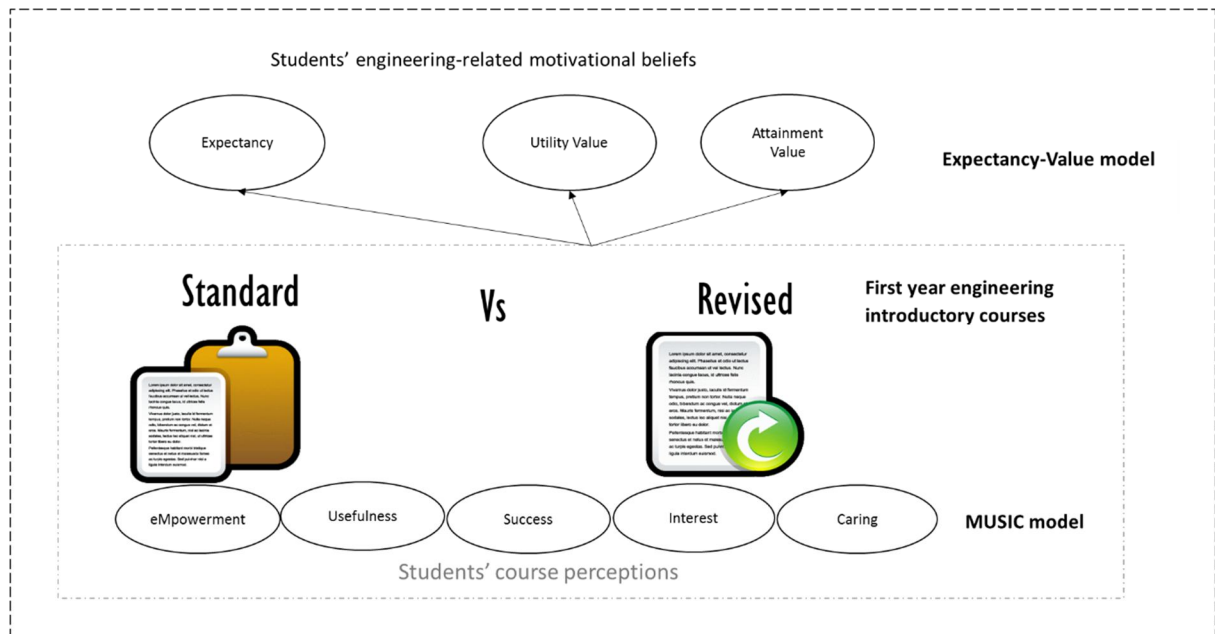


Figure 8. Representation of the Variables in this Study (Manuscript 3).

The *Empowerment* component refers to “the amount of perceived control that students have over their learning” (Jones, 2009, p. 273). Empowerment allows students

to perceive they have some *control* over their learning. The *Usefulness* component represents how suitable a *learning activity* is perceived by students for their short- or long-term goals (Jones, 2009). The *Success* component refers to the students' belief that they will succeed with a given academic task if they put forth adequate effort (Jones, 2015). The *Interest* component refers to students' perception of enjoyment of a given academic task (Jones, 2009). In other words, students continue to be interested in an academic task when they appreciate and like the given activity. The *Caring* component refers to students' perceptions that others, particularly the instructors, are concerned about their learning (Jones, 2015). When students experience relatedness, they may feel more comfortable asking and answering questions and engaging in learning activities (Jones, 2009).

The Expectancy-Value Model.

In addition to the MUSIC model, I used certain constructs of the Expectancy-Value model (Wigfield & Eccles, 2000) to examine students' engineering-related motivational beliefs. The Eccles et al. (2000) Expectancy-Value model theorizes that individual's performance, persistence, and task choices are shaped by both the individual's expectancy for success and their particular values (Wigfield & Eccles, 2000). The Expectancy beliefs component explains individuals' *ability* to perform a certain task, whereas the task-value component explains the individual inquiring about the *importance* of the task (Wigfield et al., 2006). Eccles and her colleagues tested this theory empirically, and found that students' expectancies for success are strongly related to their performance on the task, whereas students' task-values predict their course plans and enrollment decisions, even after controlling for prior performance levels (Eccles, 1983;

Meece et al., 1990).

The task-value segment of the model contains four elements: Attainment, Interest, Utility, and Cost. The *Attainment* element in the task-value part of the model refers to the *value* an individual attaches to participating in a task or the personal importance of doing well on the task (Wigfield & Eccles, 2000). *Interest* value refers to the satisfaction that results from performing a task, whereas *Utility* value refers to how useful or how well a required task is related to an individual's current or future goals. Lastly, perceived *Cost* refers to any demand related to engaging in the task, or the amount of effort necessary to succeed, and the lost benefits that may result from an individual's choice (Wigfield & Eccles, 2000).

The MUSIC Model and Motivational Beliefs

Theoretical evidence shows connections between students' educational experiences to their domain identification and domain-related motivational-beliefs, particularly in domains such as engineering (Osborne & Jones, 2011). In fact, empirical research evidence supports the association of students' perceptions of the MUSIC model components with students' motivational beliefs. Based on data from first-year engineering students, Jones et al. (2014) established that students' perceptions of an introductory engineering design course were related to their broader engineering motivational beliefs. In that study, all the MUSIC model components predicted students' engineering identification: Empowerment, Usefulness, Success, Interest, and Caring. Engineering Utility was predicted by Empowerment and Success, engineering program belonging was predicted for all the MUSIC model components, and engineering program expectancy was predicted by all the MUSIC model components, except Interest. The

effects of students' course perceptions on students' motivational beliefs was subsequently analyzed in another study (Jones et al., 2016). Findings from Jones et al. (2016) study also support the relation of the MUSIC model components with students' motivational beliefs, suggesting that the MUSIC model components were statistically related to students' broader engineering beliefs, which then predicted their engineering major and career goals.

The primary goal of this study is to extend Jones and colleagues' (2014, 2016) findings of the relationship between students' perceptions of the MUSIC model component in a first-year engineering introductory course and students' engineering-related motivational beliefs. Unlike the work performed by Jones and colleagues, this study has employed the Expectancy-Value model (Wigfield & Eccles, 2000) as a theoretical lens to analyze students' motivational beliefs.

Expectancy-Value theory is a model that has proven useful in examining course enrollment and academic and career choices. This model has been linked to predict students' intentions, choices, and persistence in engagement of a determined task or activity (Wigfield & Eccles, 2000). Specifically, this model has been used to associate students' perceptions to their engagement and performance (Wang & Eccles, 2013). Expectancy-Value model describes how people's perceptions of activities and task demands can affect their goals and general self-schema, which in turn affects their expectation for success, and subjective value of the activities or tasks (Wigfield & Eccles, 2000). In this study, I analyzed how students' perceptions of the introductory engineering course are related to their engineering-related expectancy for success and values. It is important to study students' engineering-related Expectancy-Value beliefs because these

beliefs have been shown to predict important outcomes such as students' achievement, career plans (Jones et al., 2010), and choices to become engineers (Matusovich et al., 2010). In addition, Jones et al. (2010) found that students' expectancy and value beliefs decreased over the first year. The link between first-year students' course perceptions and their Expectancy-Value beliefs can provide insights about appropriate structures of engineering courses that can at least mitigate drops in students' Expectancy-Value beliefs having a better chance to motivate them to pursue engineering careers.

Additionally, I extended the analysis by comparing the relationship between students' perceptions and Expectancy-Value beliefs in two versions of an introductory engineering course, *standard* and *revised*. First year engineering programs have implemented significant changes and revisions nationwide. The case in this study is the revision of one of the courses in the engineering sequence in the first-year program. The present study sought further understanding and discussion by comparing the extent that perceptions of the students enrolled either in the standard or revised version the course are related to their Expectancy-Value engineering-related beliefs. Figure 9 shows a modified version of the model of identification (Osborne & Jones, 2011) empirically tested by Jones et al. (2014, 2016) showing the relationship between course perceptions and students' motivational beliefs. Structural paths have been examined from each component of the MUSIC model to each of the motivational beliefs.

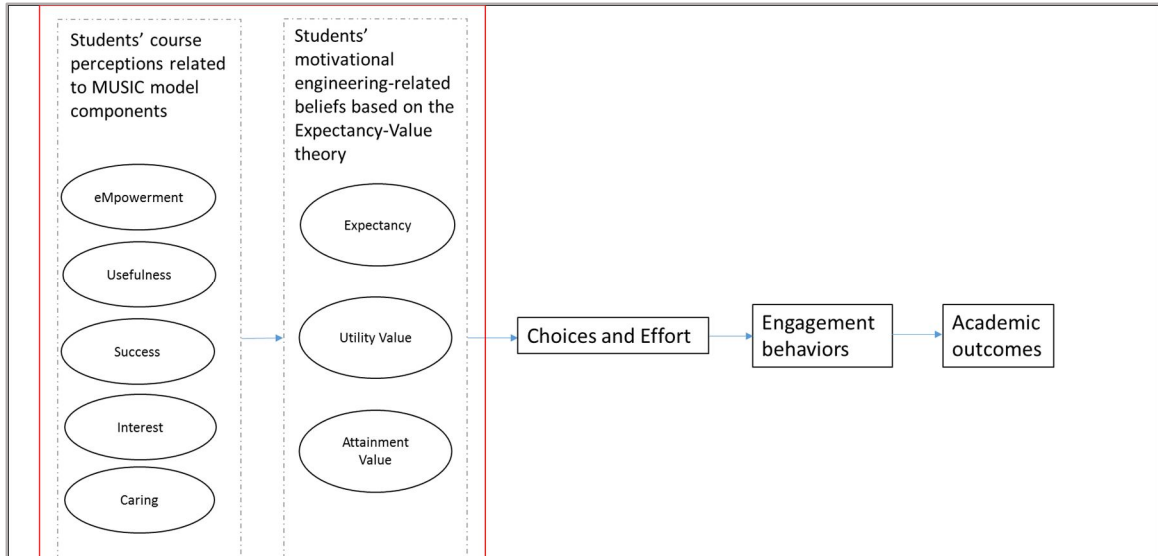


Figure 9. Modified Version of the Identification Model (Osborne & Jones, 2011) to show the Constructs Included in this Study (Manuscript 3).

Methods

This study examined the relationship between students' course perceptions and Expectancy-Value beliefs via exploration of the relationship between each of the components of the MUSIC model: eMpowerment, Utility, Success, Interest, and Caring and Expectancy-Value constructs. I used existing data that included items that are representatives of the constructs involved in the Expectancy-Value model. Because of the use of existing data, only three of the five constructs that conform the Expectancy-Value model: Expectancy, Utility, and Attainment value were analyzed (the Interest construct was not included in the existing data set and the Cost construct was measured by only one item). The purpose of this manuscript was to determine to what extent first-year engineering students' course perceptions based on the MUSIC model components relate to students' Expectancy-Value engineering-related beliefs. These relationships were analyzed for two different courses, the *standard* and the *revised* version of an introductory engineering course. This section will describe the methods by which data

was collected, and the analytical methods that were used to test the relationships between the variables. The results of this study provide researchers more evidence of the validity of the instruments used in existing studies (Jones et al., 2014; Jones et al., 2016) and inform practitioners and course developers about the structure design of engineering introductory courses. Based on existing research evidence, my hypothesis stated that there would be significant relationships among the students' course perceptions and their Expectancy-Value beliefs.

Institutional review board.

A research application form was submitted to the Institutional Review Board at the University. To protect the identities and privacy of the students included in the study, the participants were assigned an anonymized and unique ID that did not allow the students to be identified. The Institutional Review Board reviewed the application and authorized the use of student records for this study.

Data collection.

This study used data previously collected by the engineering department, wherein the two versions of the introductory engineering courses were offered. Secondary data analysis is the use of existing data to investigate research questions others than those for which data were originally collected (Vartanian, 2010, p.3). The main advantages to using existing data is speed and economy. In addition, the existing data was collected from a population ideal for this study. The existing data were used as measures of students' perceptions and motivational beliefs of each of the courses included in this study, which allows for comparisons between the two groups of students. The pre-existing data used for this study had been collected through a survey conducted at the end

of the semester, in which both versions of the course had been offered.

The instrument.

This study is confirmatory in nature because its objective is to determine to what extent a *priori* model (i. e Osborne & Jones, 2011) is consistent with novel empirical data. The instrument used to collect the data about students' perceptions was the MUSIC model of academic motivation inventory developed by Jones (2009). The instrument was used intact as it was developed. Data about students' motivational beliefs were analyzed using items that are representatives of the constructs involved in the Expectancy-Value model. These items have been used to measure specific constructs related to engineering motivational beliefs e.g. (Jones et al., 2014; Jones et al., 2010; Jones et al., 2016). For the current study, I selected the constructs that better represented the Expectancy-Value model. All the items were rated using a 6-point Likert-type scale ranging from *strongly disagree*= 1 to *strongly agree*=6. The survey instructions for this study included an explicit statement as follows: 1) "When asked about engineering-related courses, please refer to your math, science, and engineering courses" and 2) "In answering, please think about engineering as a field, not any one particular course". These instructions were included so participants would not limit their responses to the introductory engineering courses required for all engineering students (Jones et al., 2010).

Students were invited to complete the survey along with other demographic questions, motivational constructs, and questions about the course content and outcomes. Participants completed the survey during the last three weeks of the course. An initial email, as well as two reminder emails were sent providing a link to the online questionnaire. The completion of the questionnaire was deemed a homework

assignment; nonetheless, students were assured of their privacy and that instructors would not have access to the individual answers.

Validity and reliability.

For this study, the validity of the survey was addressed by evaluating construct validity. Constructs are defined as “processes that are internal to an individual” (Moskal et al., 2002, p. 351). These processes allow the individual to make sense of a determined concept. Thus, construct validity allows making implications from a sample to the higher order of constructs that they represent (Shadish et al., 2002). Researchers use several strategies to obtain evidence for construct validity. For example, using statistical procedures such a factor analysis is a common way to obtain evidence for construct validity. Even though exploratory factor analysis had been conducted with the MUSIC model components, e.g., Jones et al., (2016), I conducted an exploratory factor analysis (EFA) to identify underlying factor structures as well as those items that did not fit into any existing factors. The purpose of this step was to explore the model that represented the specific data for this study (Costello & Osborne, 2005; Lomax & Schumacher, 2012). A CFA then was conducted to confirm and refine the factor structure previously identified through EFA.

Internal consistency is frequently used to demonstrate reliability of existing survey instruments. Cronbach’s alpha coefficient is generally used to measure internal consistency reliability among a group of items combined to form a construct. The reliability of the survey analyzed for this study was addressed by running an internal consistency test calculating this coefficient. Although values of 0.70 are accepted, values of alpha exceeding 0.80 are desired (Kline, 2013; Nunnally, 1978). These general

guidelines need to be used with caution because the value of the Cronbach's alpha coefficient depends on the number of items in a construct (Field, 2009). For this reason, the Spearman-Brown formula was used in cases where a construct has less than 10 items in a construct since Cronbach's alpha is sensitive to number of items in a construct (Alsawalmeh & Feldt, 1999). That is to say, tests of fewer than ten items are unlikely indicated as being reliable. Spearman-Brown formula is a correcting formula that compensate this in constructs with less than ten items (Kline, 2013).

Participants and setting.

The participants in this study are general first-year engineering students from the same cohort enrolled in either the standard or the revised version of a required introductory course at a large, public university in the mid-Atlantic United States. The engineering program included in this study fits into the taxonomy of engineering matriculation practices, developed by Chen and colleagues (2013), as a First-Year Engineering (FYE) program. Students are admitted to the college of engineering as general engineering students, and are required to take an introduction to engineering sequence during their first-year. In addition to those first-year introductory courses, the college counts on a general academic advising, and a living learning community as part of the structure of its first-year program.

Students were randomly placed into either version of the course at the beginning of the semester. All students were emailed asking them to complete the survey, which was open and available to the students for a period of three weeks.

Data analysis.

Descriptive statistics were analyzed to better understand data distribution and

frequencies of the variables in the study. Completed participant scores were averaged by components of the MUSIC model and the Expectancy-Value constructs. Data was analyzed using SPSS 24.0 software. Prior to conducting the structural equation modeling, data screening process was performed in order to ensure the data was reliable and valid for testing causal relationships. Specifically, data screening was focused on three specific issues: 1) missing data, 2) outliers, due to unengaged responses, and 3) Multicollinearity issues (Gaskin, 2012). Little's Missing Completely at Random (MCAR) test was used to determine if the data were missing randomly or non-randomly. Unengaged responses such as those respondents with the same answers (3, 3, 3, 3) for every single survey item was identified and removed because these responses tend to throw off results (Gaskin, 2012). Because multiple variables are predicting the dependent variables, multicollinearity testing is suggested. Multicollinearity was assessed by using the variance inflation vector (VIF) which measures the inflation in the variances caused by correlated predictor variables (Kutner, Nachtsheim, & Neter, 2004).

The purpose of this manuscript is to determine to what extent first-year engineering students' course perceptions based on the MUSIC model components relate to students' Expectancy-Value engineering-related beliefs.

Structural Equation Modeling.

Structural equation modeling is utilized to discover existing relationships among the constructs in a model. That is, it is used to examine a series of dependent relationships simultaneously. Both a general model as well as individual parameters within a particular model can be tested using SEM techniques (Wang &, 2012). The focus of structural modeling is on estimating relationships among hypothesized latent

constructs (Schreiber, Nora, Stage, Barlow, & King, 2006). A latent construct is anything that has been measured indirectly by other items; it cannot be directly observed. A latent model was tested because it is more accurate. All the four MUSIC model components were correlated (Empowerment, Usefulness, Success, and Caring) and all the three Expectancy-Value constructs were correlated (Utility, Attainment, and Expectancy values); 12 paths were extended from each of the MUSIC model components to the three Expectancy-Value constructs.

The number of parameters, degrees of freedom (df), chi square (χ^2), and model fit values were estimated using the SPSS added module called Analysis of Moment Structures (AMOS) specially used for Structural Equation Modeling, path analysis and confirmatory factor analysis. The chi-square statistic (χ^2) is used to test the fit of the model, its statistical significance indicates rejection of exact fit. The chi-square statistic is often found to be statistically significant however the model is a reasonable representation of the theory. Thus, additional fit indices such as CFI (Comparative Fit Index), SRMR (standardized root mean square residual), and RMSEA (root mean square error of approximation) were used to assess the model-data fit. These three fit indices were considered because represent the three major index classes used: absolute fit index (SRMR), parsimonious fit index (RMSEA), and incremental fit index(CFI) (Hu & Bentler, 1999). The CFI varies between 0 and 1, with values closer to 1 indicating better fit, values above .90 representing reasonable fit, and values close to and above .95 representing excellent fit (Hu & Bentler, 1999). The SRMR also varies between 0 and 1, but values closer to 0 indicate better fit. SRMR values less than .09 is the threshold guideline suggested by Hu and Bentler (1999). The RMSEA also varies between 0 and 1

and values closer to 0 indicate better fit. RMSEA values less than .05 indicate good fit and values less than .01 indicate moderate fit, and greater than .10 bad fit (Hu & Bentler, 1999).

The choice of a correlational approach for this study is made with the purpose to gain insights about how students' course perceptions may correlate to their Expectancy-Value beliefs. This type of study allows the exploration of the relationship of variables through hypothesis testing (Creswell, 2012), as well as enabling testing of the existing model originally developed by Osborne and Jones (2011) and tested empirically in the engineering domain (Jones et al., 2014; Jones et al., 2016). Further, Structural Equation Modeling (SEM) "allows the expression of all of these relationships within one inclusive model rather than requiring the researcher to break up the relationships into a series of discrete hypotheses, tested by separate analysis" (Rotenberg, 2006, p. 236). Thus, SEM is an appropriate technique to analyze all the variables and hypothesized relationships presented in the model. The use of SEM allowed the expression of these relationships simultaneously. The structural model was focused on evaluating the goodness of fit between the hypothesized model and the sample data. Figure 10 shows the variables and paths that were analyzed in this study being performed on the two versions of the engineering introductory course.

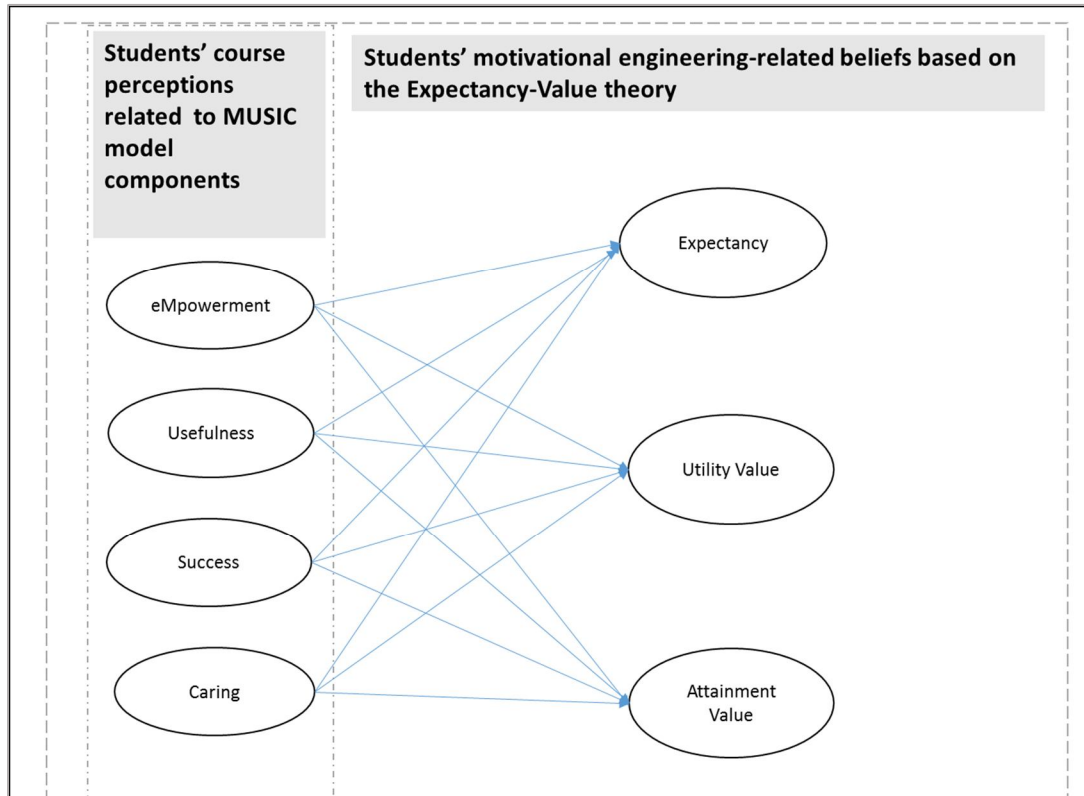


Figure 10. Variables and Paths Analyzed in this Study using SEM (Manuscript 3).

Results

Data screening.

I performed a Little's Missing Completely at Random (MCAR) test to determine if the data were missing randomly or non-randomly. The results showed that missing data was completely at random. The Expectation Maximization (EM) algorithm (Muthén, 1998) was used to address missing data because this algorithm has shown to be one of the best ways to deal with missing responses because it is a "natural generalization of maximum likelihood estimation to the incomplete data case" (Do & Batzoglou, 2008, p. 897). Additionally, I screened the data looking for unengaged responses, I found some cases where the same answer was given to all the items in the survey. These cases were removed from the datasets. Because I had multiple variable predicting the dependent

variables, I ran a Multicollinearity test. Multicollinearity was assessed by using the variance inflation vector (VIF) which measures the inflation in the variances caused by correlated predictor variables (Kutner et al., 2004). All the variance inflation factors were below 2 indicating no Multicollinearity issues in the data (Hair, 2010).

Construct validity.

Exploratory factor analysis: MUSIC model of academic motivation and motivational beliefs

I conducted a principal component analysis (PCA) on the 26 items in the MUSIC model inventory and the Motivational Beliefs items. Orthogonal rotation (varimax) was used in both cases. Varimax rotation attempts to maximize the dispersion of loadings within factors (Field, 2009). In general, for the MUSIC model inventory, the results suggested that three of the factors had the highest loading on the factor with the other items in the same subscale. This is, all of the Caring items (C1-C6) loaded highest on factor 2, all of the Empowerment items (E1-E5) loaded highest on factor 3, and all of the Success items (S1-S4) loaded highest on factor 4. Usefulness and Interest items (U1-U5 and I1-I5 respectively) loaded into the same factor. Therefore, these two components were combined as a single factor. For the Motivational Beliefs survey, the results suggested that all the factors had the highest loading on the factor with the other items in the same subscale. All of the engineering Utility items (B5-B10) loaded highest on factor 1, all of the engineering Expectancy items (D1-D5) loaded highest on factor 2, and all of the Attainment items (B1-B4) loaded highest on factor 3.

Confirmatory factor analysis MUSIC model and motivational beliefs

Confirmatory factor analysis (CFA) was conducted and the measurement model

was re-specified to improve the model-data fit, which is a common statistical practice. Specifically, I removed six of the 26 items related to the MUSIC model components. I used AMOS (Analysis of a Moment Structures) software version 24 to conduct the CFA using the maximum likelihood estimation method. Kline (2005) suggests the four following judgments of fit associated with the CFAs: (a) the model chi-square statistic, (b) the comparative fit index (CFI), (c) the standardized root mean square residual (SRMR), and (d) the root mean square error of approximation (RMSEA). These indices can vary between 0 and 1; higher values for the CFI indicate better fit while that lower values for the SRMR and the RMSEA indicate a better fit. All the latent variables were allowed to covary. The fit indices were as follows for the MUSIC model components: SRMR= 0.04, RMSEA= .057, and CFI= .966. For the Motivational Beliefs constructs, according to the modification indices in the model, two Expectancy and two Attainment items were allowed to covary. The resulting fit indices were as follows: SRMR= 0.06, RMSEA= .05, and CFI= .98. These scores indicate a good fit between the model and the observed data (R. Kline, 2005).

Reliability.

Reliability of the MUSIC model and the motivational beliefs constructs were explored calculating the Cronbach's coefficient alpha values to measure internal consistency. The resulting values (see Table 20) range between 0.82 and 0.96 indicating good levels of reliability (Nunnally, 1978).

Table 20.

Internal Consistency Reliability-Cronbach's Alpha and Descriptive Statistics

<i>Construct</i>	<i>N of Items</i>	<i>Cronbach's Alpha</i>	<i>Course Type</i>	<i>Mean</i>	<i>SD</i>	<i>N</i>
Empowerment	4	.88	Standard	4.27	0.96	808
		.88	Revised	4.20	0.99	240
Usefulness	6	.93	Standard	4.10	1.11	808
		.92	Revised	4.09	1.14	240
Success	4	.88	Standard	4.66	0.84	808
		.89	Revised	4.53	0.92	240
Caring	4	.87	Standard	4.98	0.78	808
		.84	Revised	5.10	0.73	240
Attainment	4	.82	Standard	5.19	0.74	810
		.84	Revised	5.22	0.74	240
Utility	6	.94	Standard	5.27	0.96	810
		.96	Revised	5.24	1.08	240
Expectancy	5	.89	Standard	4.71	0.77	810
		.90	Revised	4.82	0.68	240

Correlation matrix of the latent variables.

The correlation matrices of the latent variables are presented in Table 21 for the standard model and Table 22 for the revised model.

Table 21.

Correlation Matrix Among the Latent Variables in the Standard Model

	Attainment	Utility	Expectancy	Empowerment	Usefulness	Success
Utility	.441**	–				
Expectancy	.483**	.253**	–			
Empowerment	.308**	.111**	.291**	–		
Usefulness	.337**	.192**	.246**	.670**	–	
Success	.370**	.284**	.633**	.508**	.463**	–
Caring	.249**	.184**	.188**	.356**	.279**	.353**

Table 22.

Correlation Matrix Among the Latent Variables in the Revised Model

	Attainment	Utility	Expectancy	Empowerment	Usefulness	Success
Utility	.408**	–				
Expectancy	.528**	.236**	–			
Empowerment	.161*	.051	.070	–		
Usefulness	.248**	.088	.011	.650**	–	
Success	.370**	.182**	.439**	.446**	.564**	–
Caring	.094	.076	.096	.311**	.485**	.389**

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

The correlations among the latent variables are less than 0.7 in all the cases indicating that, although the variables are related, there are no issues related to Multicollinearity and that the motivation constructs are distinct.

Models.

The two models corresponding to each of the versions of the introductory engineering course were used to test the relationship between the four components of the

MUSIC model (Empowerment, Usefulness, Success, and Caring) and the three Expectancy-Value motivational beliefs constructs (Expectancy, Utility, and Attainment, values). The examination of the relationships between the MUSIC model components and the Expectancy-Value motivational beliefs were based on prior research enabling testing the existing model originally developed by Osborne and Jones (2011), tested empirically in the engineering domain (Jones et al., 2014; Jones et al., 2016). These models have indicated that the students' perceptions of engineering courses based on the MUSIC model components have effects on students' engineering-related motivational beliefs.

The focus of structural modeling is on estimating relationships among hypothesized latent constructs (Schreiber et al., 2006). A latent construct is anything that has been measured indirectly by other items; it cannot be directly observed. A latent model was tested because it is more accurate. All the four MUSIC model components were correlated (Empowerment, Usefulness, Success, and Caring) and all the three Expectancy-Value constructs were correlated (Expectancy, Utility, and Attainment values); 12 paths were extended from each of the MUSIC model components to the three Expectancy-Value constructs. The number of parameters, degrees of freedom (df), chi square (χ^2), and model fit values were estimated using the SPSS added module called Analysis of Moment Structures (AMOS) specially used for Structural Equation Modeling, path analysis and confirmatory factor analysis. The chi-square statistic (χ^2) is used to test the fit of the model, its statistical significance indicates rejection of exact fit, however since this index is often found to be statistically significant although the model is a reasonable representation of the theory, additional fit indices are suggested to assess

model-data fit (Hu and Bentler, 1999). Thus, additional fit indices such as CFI (Comparative Fit Index), SRMR (standardized root mean square residual), and RMSEA (root mean square error of approximation) were used to assess the model-data fit. Hu and Bentler (1999) suggest a cutoff value close to .95 for CFI; a cutoff value close to .08 for SRMR; and a cutoff value close to .06 for RMSEA as needed before we can conclude that there is a relatively good fit between the hypothesized model and the observed data. The fit indices to assess the model-data fit for each model are listed in Table 23 for the standard model and Table 24 for the revised model. In general, these values suggested an excellent data-fit for the standard model and an acceptable data-fit for the revised model.

Table 23.

Model Fit Measures for the SEM Standard Model

<i>Measure</i>	<i>Estimate</i>	<i>Threshold</i>	<i>Interpretation</i>
Chi-square	1279.81	--	--
DF	442	--	--
CFI	0.954	>0.95	Excellent
SRMR	0.0436	<0.08	Excellent
RMSEA	0.049	<0.06	Excellent

Table 24.

Model Fit Measures for the SEM Revised Model

<i>Measure</i>	<i>Estimate</i>	<i>Threshold</i>	<i>Interpretation</i>
Chi-square	819.55	--	--
DF	442	--	--
CFI	0.932	>0.95	Acceptable
SRMR	0.065	<0.08	Excellent
RMSEA	0.06	<0.06	Acceptable

I examined the significance of each individual structural path. The statistically significant paths and standardized regression weights are shown in Figure 11 for the standard model and in Figure 12 for the revised model. In the standard model, Attainment value was predicted by Usefulness, Caring, and Success. Utility value was predicted by Empowerment and Success. But, Empowerment negatively predicted Utility value. Finally, Expectancy was predicted by Success only. In the revised model, Attainment value was predicted by Usefulness, Empowerment, and Success. Utility value was predicted by Success. Finally, Expectancy was predicted by Empowerment and Success.

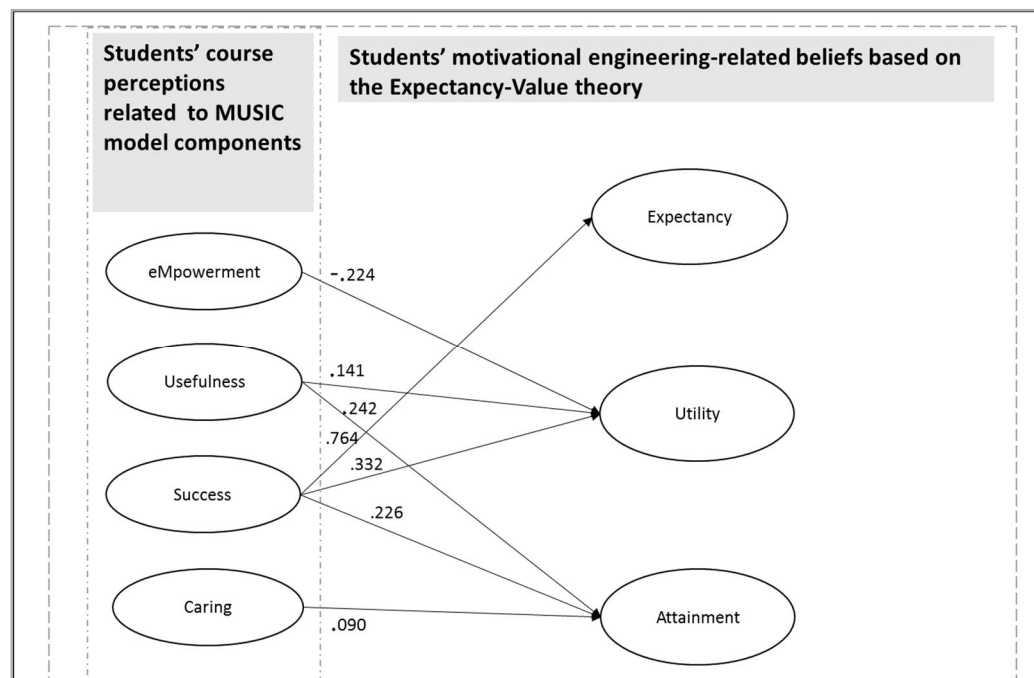


Figure 11. Final Structural Model for the Standard Version of the Course.

Note: Paths shown are significant at $p < .05$ with standardized regression weights.

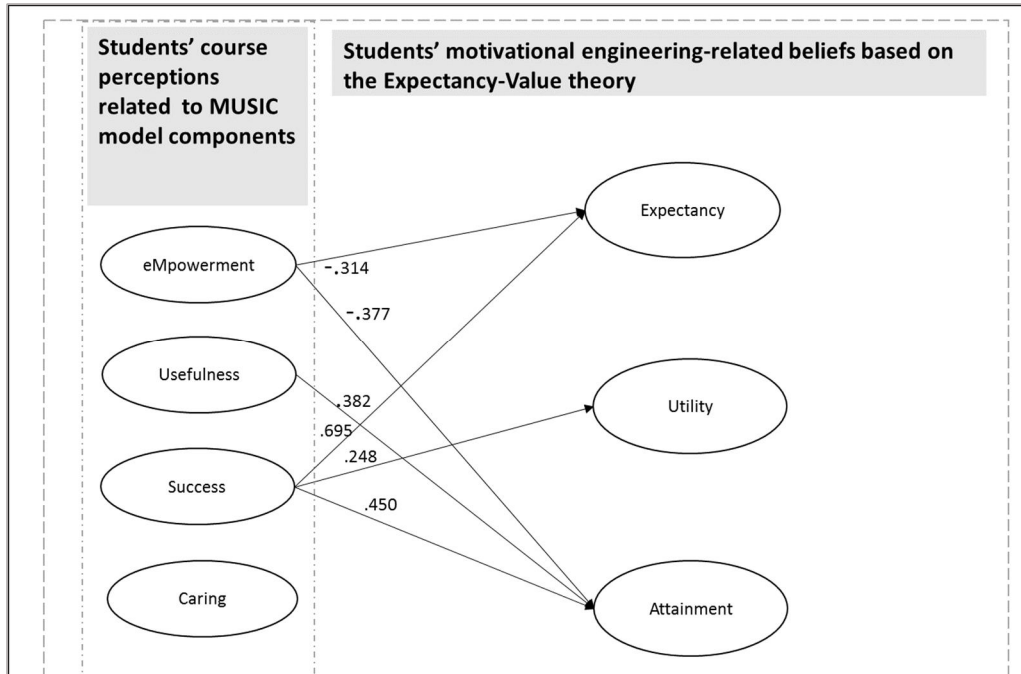


Figure 12. Final Structural Model for the Revised Version of the Course.

Note: Paths shown are significant at $p < .05$ with standardized regression weights.

Discussion

The overall research question for this study was: to what extent do first-year engineering students' perceptions, based on the MUSIC model components, in two versions of an introductory engineering course, relate to their Expectancy-Value engineering-related beliefs? Based on the fit indices of the models, both models provided a good data fit indicating that the data fit the hypothesized models with all the measured variables. Because the fit indices indicated good data fit in the baseline model for each version of the course, no post hoc modifications were performed.

The findings of this study provide evidence for the use of the MUSIC model of Academic Motivation components to be used to better understand how perceptions of first year engineering introductory courses affect students' Expectancy-Value

engineering-related beliefs. The fit indices of the models suggested a good model data-fit providing strong support for the hypothesis that students' perceptions of these courses have effect on students' broader motivational beliefs. This suggestion is interesting as it adds evidence to the idea that the MUSIC model of Academic Motivation components can be used to create learning environments, and to design and assess courses in ways that will support students' motivation to persist in engineering. This is significant as these Expectancy-Value beliefs are shown to be related to students' career choices and decisions to persist in engineering careers.

The results of this study demonstrate that the perceptions of Success, Usefulness, and Empowerment predict students' engineering-related Attainment-value beliefs. Some research has shown that the Attainment construct is equivalent to domain identification (Osborne & Jones, 2011). Eccles (2005) has noted the term Attainment value "in terms of the personal importance attached to doing well on, or participating in, a given task" (Eccles, 2005, p. 109) which is very similar to the domain identification definition provided by Osborne and Jones (2011), in which domain identification is viewed as "the degree to which an individual values a domain as an important part of the self" (Osborne & Jones, 2011, p. 333). Even though Eccles et al. define the Attainment value at the task level, they have assessed this component at the domain level, such as the mathematics domain (Eccles & Wigfield, 1995; Meece et al., 1990). Thus, Attainment refers to how important a determined domain is to the individual, in the case of this study, the engineering domain.

Other studies in similar contexts have found that all the five components of the MUSIC model of Academic Motivation are significantly related to engineering

identification (Jones et al., 2014). In another study in the same context, Empowerment, Utility, and Success were found to predict engineering identification (Jones et al., 2016). More recently, Tendhar et al (2017) found that Success, Interest, and Caring predicted engineering identification in a study that included the same sample as that in the current study. In the present study, the perceptions of Success, Usefulness, Empowerment, and Caring were significantly related to students' engineering-related identification or Attainment-value beliefs. Therefore, the results of the analysis presented in the current study showed similar results to those presented by Jones et al., (2014) and slightly different than Jones et al., (2016) and Tendhar et al. (2017). Although the current study and the one by Tendhar et al. (2017) used essentially the same sample, it is possible that the results did not exactly match because of post hoc revisions performed in the latter study. Post hoc revision is a typical statistical practice for this type of analysis. As noted, in both courses within this study, Success, Usefulness, and Empowerment predicted engineering identification or Attainment value. This suggests that we might not need all the MUSIC model components to help development of engineering identification and that some of the components of the MUSIC model can be more influential on engineering identification. This is significant because studies in similar contexts have showed that identification with engineering at the first-year level predicts students' engineering major and career intentions and goals (Jones, et al., 2014; Jones et al., 2016, Tendharet al., 2017).

Engineering Expectancy was predicted by Success in both courses. Expectancy is defined as individuals' beliefs about how well they will perform on a task (Eccles & Wigfield, 2002). Theoretical evidence suggests that expectancies for success are similar

to Bandura's (1997) self-efficacy theory, since they share similar constructs, such as individual perceptions of abilities to succeed in a task determine their performance in such a task (Meece et al., 1990). The strong relationship between Success and Expectancy is not surprising. Students who perceive they can succeed in the course will likely increase their self-efficacy, leading to an increase of belief they will succeed as an engineering major. One of the sources for self-efficacy, according to Bandura (1997), is individuals' actual performance. Instructors can affect students' actual performance by providing challenging tasks with adequate support for students to succeed (Jones, 2015). Usually, students with high levels of self-efficacy are confident in their skills and abilities, show great effort and persistence, and have high levels of academic performance (Schunk, 1991).

Engineering Utility value was predicted by Success in both courses. Utility value refers to the extent in how useful or how well a required task is related to the individual's current or future goals. Thus, it seems that students who perceived success as a result of effort and improvement also viewed engineering as a useful domain in which they would succeed. These results are consistent with some existing studies conducted in similar engineering contexts (Jones et al., 2014; Jones et al., 2016). Some research has suggested that affective memories, such as performance concerns, influence the engineering Utility value (Wigfield & Eccles, 1992). The more students perceive they can succeed the more value they attach to the Utility of engineering for their future goals.

The negative effect of the Empowerment component on engineering Utility, Attainment, and Expectancy was not expected and it is inconsistent with existing literature (Jones et al., 2014; Jones et al., 2016; Osborne & Jones, 2011). Osborne and

Jones (2011) hypothesized the relationship between Empowerment and the domain of Identification. They focused on the need for autonomy because this concept was the most closely related to Jones' conception of empowerment. They stated that through teachers' autonomy support, students can become more identified with a domain (Osborne & Jones, 2011, p. 144). However, they did suggest exploring the directionality of this relationship presented in their model. This model was tested empirically in the studies by Jones et al., (2014), Jones et al., (2016), and Tendhar et. al (2017). In the first study, Empowerment resulted positively related to engineering identification, engineering utility, engineering program belonging, engineering program expectancy, and course efforts (Jones et al., 2014). In the second study, Empowerment was positively related to engineering identification and engineering program belonging (Jones, et al.2016). The results of my study confirm findings from the study by Tendhar et al. (2017) that used the same data set; the Empowerment component was negatively related to engineering utility and engineering expectancy.

According to Jones, Empowerment refers to the students' perceptions of "having the ability to make decisions about some aspects of their learning" (Jones, 2015, p. 15). Further, Jones (2015) adds that "Empowerment can be a very powerful motivator but it can also be very scary to learners" (p. 16). It is possible that high school students just entering college might become very anxious concerning their personal learning decisions. Perceptions of Empowerment may be different between students who are just beginning college and those at higher college levels. The empowerment component is related to the Self-Determination Theory (Ryan & Deci, 2000) which establishes that autonomy, competence, and relatedness are important psychological needs to promote intrinsic

motivation. Intrinsic motivation refers to behaviors that are driven by internal rewards rather than external rewards. Self-Determination Theory suggests that classroom environments can facilitate intrinsic motivation by supporting the needs for autonomy and competence. “However, it is critical to remember that intrinsic motivation will occur only for activities that hold intrinsic interest for an individual, those that have the appeal of novelty, challenge, or aesthetic value for that individual” (Ryan & Deci, 2000, p. 59). Thus, the challenge might be to develop learning environments that empower students while at the same time are intrinsically rewarding. This finding is based on a single quantitative study at a single institution; further research should explore whether similar inconsistency exists in other contexts.

Conclusions and Future Work

Motivation to persist in engineering, or lack thereof, can be influenced by different factors; however, many students would likely benefit from classes, learning environments, and educational experiences that positively impact their academic motivation. Specifically, instructional designers and instructors can benefit from existing strategies established on well-grounded motivation theories, to design, develop, and assess the effectiveness of their classes not only related to students’ academic motivation but also relative to their own contribution to students’ broader motivational beliefs. Thus, the model presented in this study can serve to aid interested stakeholders in the design and assessment of engineering introductory courses as they impact students’ motivational beliefs.

Findings from this study suggest that the MUSIC model of Academic Motivation components can be used to better understand how perceptions of first year engineering

introductory courses affect students' engineering-related motivational beliefs. These findings are important because instructional designers can modify their pedagogical approaches accordingly to support engineering motivational beliefs. This is of great importance especially for first year engineering students as this is a crucial time when the major amounts of drop-outs occur. Simultaneously, students' Expectancy-Value related beliefs have been found to decrease during the first year. However, motivational beliefs have been found to predict career plans, declared major choices, and decisions to persist in engineering. Further research could add to the models presented in this study other variables that could provide a deeper understanding of how first year engineering students' motivational beliefs are developed. Qualitative research such a verbal or written descriptions could benefit our understanding about how students' perceptions of the course impact their motivational beliefs.

Limitations

Although the research questions as stated in this study were addressed, there were some noticeable limitations. This study did not include specific strategies based on the MUSIC model that could provide more information about which elements in the courses may impact students' perceptions and therefore their engineering-related motivational beliefs. This is especially important for instructors who might be interested in which practices are more likely to support each of the components of the MUSIC Model for first-year engineering students. Additional research including the analysis of which elements and strategies in the design and delivery of the courses are more supportive of the MUSIC Model components would be beneficial for the overall improvement of the study.

The analysis in this study did not include demographic variables such as gender, race, GPA or other background variables that have been shown to influence students' motivational beliefs. Inclusion of these variables was outside the scope of this study. However, models such as those developed in this study could provide more information as well as reduce bias by containing relevant variables that contribute in the development of students' motivational beliefs.

Finally, this study included data from only one comprehensive research university. Therefore, while the results may be useful to inform first year programs at other universities, they may not be generalizable to other first year students programs. It would be necessary to replicate the analysis in other institutions to represent better the population of first-year engineering students.

Chapter Five

Conclusions and Implications

The purpose of this dissertation was to analyze how students' perceptions and engineering-related motivational beliefs differed between students enrolled in the standard versus the revised versions of an introductory engineering course, and to what extent students' perceptions of the courses predicted their engineering-related motivational beliefs. To answer these questions, I conducted three studies addressing three general research questions. In this chapter, I focus on summarizing the main outcomes of each manuscript, describing potential implications for students, researchers, and practitioners in engineering education, and identifying potential opportunities for future work based on the results of this dissertation study.

Main Outcomes

Course perceptions.

Students' academic motivation depends largely on students' perceptions of their experiences in the class (Jones, 2015). This study provided validity to the use of the MUSIC model of Academic Motivation to measure students' perceptions of introductory engineering courses. Additionally, data from the two group of students, those enrolled in the standard and in the revised version of the course, indicated that students' perceptions of the Usefulness and Interest components based on the MUSIC model of Academic Motivation were seen as the same construct. This was observed through the Exploratory Factor Analysis (EFA) and confirmed in the Confirmatory Factor Analysis (CFA). This finding suggests that for first year engineering students included in this study, the differences between Usefulness and Interest appears to be somehow subtle. The more

interesting students perceive the content and instructional activities in the course, the better students perceive the course content and activities as useful for their short- or long-term goals. This finding suggests that for this population of students, items from these two constructs could be combined, under a broader construct such as relevance including both students' interests and goals, for example see: Assor, Kaplan, and Roth, 2002.

In answering the first research question of the study, I compared students' perceptions based on the MUSIC model of Academic Motivation components (Empowerment, Usefulness, Success, and Caring) between the two group of students, those enrolled in the standard and revised versions of the course. There were not statistically significant differences between students' perceptions of the components Empowerment and Usefulness. On the other hand, students' perceptions of Success and Caring were statistically and significantly different between the two student groups suggesting students perceived the two versions of the course differently. Students in the standard version of the course had higher perception levels of Success, whereas students in the revised version of the course had higher perceptions of the Caring component.

Success refers to students' beliefs that he or she can succeed if they put in adequate effort (Jones, 2009). It is possible that, since this was the first time the new version of the course (revised) was offered, clear expectations of activities or assignments in the course had not yet been established. The time when the survey was applied could also influence on students' perceptions of this component. The survey was open during the last four weeks of the semester, most of students completed the survey next to the last week of the semester. A concern may be that the ability of students to accurately estimate their level of Success at the end of the course might be influenced by the level of

uncertainty about their grades in the course.

Caring refers to students' perception that others, primarily their instructors, are interested in their learning (Jones, 2009). It is difficult to speculate why Caring was significantly different in the two groups of students since the data include different instructors teaching different sections of each course; further research could disaggregate data by instructors providing more insight for this finding. These differences showed small effect sizes indicating that the *importance* of these significant differences is small (Cohen, 1988). However, it must be considered that if it could be shown that students' perceptions of an introductory engineering course would improve by a little, as indicated by the small effect size, then this could be a very significant improvement, particularly if the improvement can be sustained over time. Moreover, the results of the comparison of students' perceptions should be interpreted according to their practical significance in first year engineering education.

In sum, the most notable findings from manuscript 1 include: a) students' perceptions of the Usefulness and Interest components were seen as the same construct, b) there were not statistically significant differences between students' perceptions of the components Empowerment and Usefulness, and c) students' perceptions of Success and Caring were statistically and significantly different between the two student groups.

Expectancy-Value engineering-related beliefs.

In answering the second research question, I compared students' Expectancy-Value beliefs between the two group of students and within the same group of students in both versions of the introductory engineering course. First, when comparing students' Expectancy-Value engineering-related beliefs between the two groups of students, there

were not statistically significant differences either at the beginning or at the end of the semester. This result supports the notion that there are a variety of background factors that influence Expectancy-Value beliefs. Second, when comparing students' Expectancy-Value beliefs within the same group of students, results were mixed. In the standard version, all the three Expectancy-Value constructs were statistically significant lower at the end of the semester. The identification of differences in all three motivational constructs, Expectancy, Attainment, and Utility value, between the beginning and the end of the semester in the standard course replicates findings from prior studies that indicate that students' engineering-related motivation decreases over the first year in an engineering program. On the other hand, there were no statistically significant differences in such motivational beliefs from the BOS to the EOS in students' in the revised version of the course. This finding is meaningful given the practical implications this could have in real contexts and encourages to keep expanding and adjusting courses that better support students' academic motivation.

In conclusion, the most important findings from manuscript 2 include: a) there was no significant difference in the motivational constructs between the two versions of the course either at the beginning or at the end of the semester, b) in the standard version of the course, the three motivational constructs: Expectancy, Attainment, and Utility values were found to have declined significantly, and c) in the revised version of the course, there were not statically significant differences in the three constructs between the beginning and the end of the semester.

Relationship between students' perceptions and their Expectancy-Value engineering-related beliefs.

From answering the third research question, we have a better understanding for how students' perceptions of the courses are related to their Expectancy-Value beliefs. The overall results of the structural equation model analysis illustrate that students' perceptions of the introductory engineering courses are related to their Expectancy-Value engineering-related beliefs. These relationships are noteworthy, as Expectancy-Value beliefs have been shown to be related to students' choices and decisions to persist in engineering. Likewise, these results are useful for instructors, researchers, and policy-makers who attempt to improve students' retention rates in engineering.

The negative effects of students' perceptions of Empowerment on Utility value in the standard course, and Expectancy and Attainment in the revised course were unexpected. Prior studies in similar contexts have found that Empowerment is related positively to Expectancy, Utility and Attainment value (Jones et al., 2014; Jones et al., 2016). Another study conducted previously by Tendhar et. al (2017) using the same data set as that included in this study reported a negative relationship between the Empowerment component and engineering Utility and Expectancy. In conclusion, the results of my study contradict those in the studies by Jones et al., (2014) and Jones et al., (2016) but are similar to those presented by Tendhar. et al (2017). This is not surprising because both studies used the same data set. In fact, these results add internal validity evidence to the findings as published by Tendhar (2017) giving greater confidence to the negative relationship between students' perceptions of Empowerment and Utility, Expectancy, and Attainment engineering-related beliefs. Perhaps to mitigate this effect,

we need to strive that the choices and control we provide to students regarding their learning are meaningful to them. For instance, according to Katz and Assor (2007), choices are motivating when they: 1) are relevant to students' interest and goals giving autonomy support; 2) are not too numerous or complex providing competence support; and 3) are aligned with the values of the students' culture giving relatedness support (Katz & Assor, 2007; Ryan & Deci, 2000). In fact, fostering relevance of choices has been found to support better students' perceptions of learning (Assor et al., 2002).

The Usefulness component was related to the Utility value in the standard course and to the Attainment value in both versions. The relationship between Usefulness and Utility value was expected because this component is based on the Utility value component in Expectancy-Value theory. The effect of the Usefulness component on Attainment value was common for both courses suggesting that students might feel more identified with engineering if they perceive the learning activities are useful to their short- or long-term goals.

Success was the strongest predictor of students' engineering-related Expectancy-Value beliefs. This finding was common for both versions of the course. This finding is thought-provoking as it suggests that those first-year engineering students who perceive they can succeed in the course if they put forth the effort are more likely to persist by both believing they can succeed in engineering and having the desire and finding the importance to engage in engineering-related activities. This combination is significant because the mixture of both high-self concepts and values has been suggested as essential to increase the likelihood of persevering and pursuing a career (Simpkins et al., 2006).

Caring was found to be positively associated with Attainment in the standard version of the course. The Caring component is based on the relatedness need described in the Self-determination theory (SDT), which postulates three basic psychological needs for humans' well-being: competence, autonomy, and relatedness (Ryan, 1991). Relatedness is the wish or desire to interact with, or to be connected to, and experience concern for other people (Ryan, 1991). Some research suggests that relatedness to teachers is associated with greater internalization of school-related motivational behaviors (Ryan, Stiller, & Lynch, 1994), thus, providing students with classroom environments that make them feel cared for by the instructors may be one way to increase Attainment value.

In sum, a summary of findings from manuscript 3 include: a) the fit indices of the models suggested that the model was indeed a good fit; b) the Caring component was found to be positively associated with Attainment value in the standard version of the course, c) the Usefulness component was related to the Utility value in the standard course and to the Attainment value in both versions of the course, and d) the success component was the strongest predictor of students' engineering-related expectancy-value beliefs.

Implications for Stakeholders

The results of this study have several implications for students, instructors, and researchers in the realm of engineering education. Students will likely benefit from instructors' empathy and consideration with regard to relationships between students' perceptions of the courses and their associated activities, and the students' engineering-related motivational beliefs. In particular, and bearing in mind, students' engineering-

related motivational beliefs have a substantial effect on students' college majors and career goals. Secondly, instructors can modify their pedagogical practices as necessary by understanding how students perceive the courses. The MUSIC model offers the MUSIC Model Inventory as a practical way to measure students' perceptions, further there are specific teaching practices linked to each of the components that can be easily implemented to support students' academic motivation. This information is especially useful for the instructors and developers of course content and pedagogy.

For example, results of this study suggest that students' perceptions of Success affect both their expectancy and value engineering-related motivational beliefs. Researchers have suggested that past performance, observation of others, feedback from others, and emotional reactions (Pajares & Schunk, 2001) are major contributors to students' beliefs of Success. Further, Jones (2015) suggests specific teaching strategies that might help to support positive students' perceptions of Success in courses as shown in Figure 13.

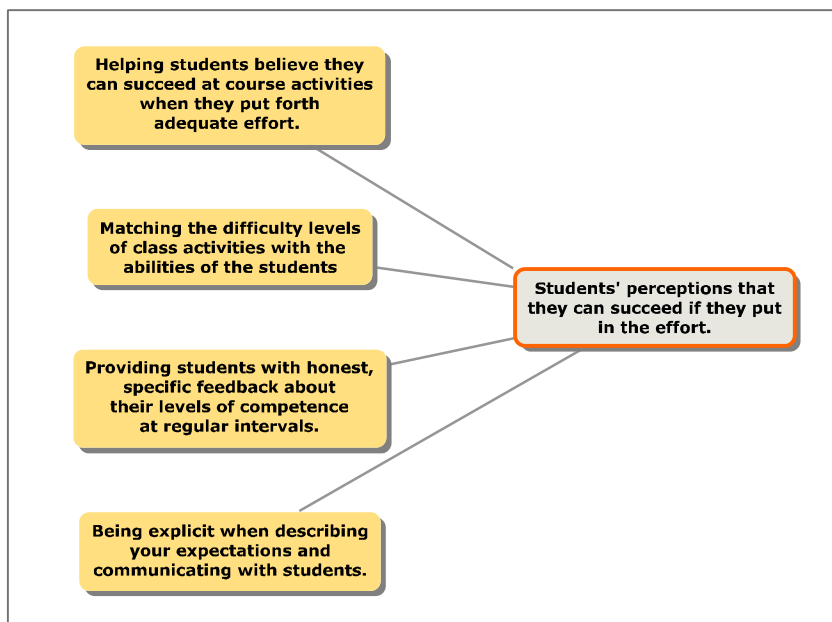


Figure 13. Success Strategies Suggested by Jones (2015).

Encouraging students to *believe* they can succeed might be one of the most powerful strategies instructors can implement. This might be especially powerful for students from underrepresented populations that usually doubt their own abilities to succeed (Ong, 2005). Students who believe they can succeed might or might not be more motivated in class; however, students who do not believe they can succeed tend to be less engaged. Matching difficulty levels is also essential because if activities are too easy for students, they might find them boring and become unmotivated in class. On the other hand, if difficulty levels are too high for students' abilities, their performance in these activities might affect their beliefs that they can succeed, and therefore they become less motivated to put in any effort. Regular feedback also influences perceptions of Success by informing students about their competencies regarding learning activities. This feedback might be more useful at the freshman level if instructors explicitly state their expectations in assignments. Students might benefit from this by adjusting their learning strategies according to instructors' expectations.

One of the most noteworthy findings of this study is the negative relationship between students' perceptions of Empowerment and their engineering-related motivational beliefs. This finding suggests that giving students some power over certain aspects of their learning negatively affects their Expectancy for success and value in engineering. According to existing research, individuals are more motivated when they feel autonomous and can make decisions about things that affect them (Ryan & Deci, 2000). However, this appears to not be the case for first-year engineering students in this study, where providing those students more autonomy might have an opposite effect, making them more anxious and nervous about engineering.

Figure 14 represents some strategies suggested by Jones (2015) that when used appropriately at the students' level might act as effective students' motivators. On the left side, are general strategies suggested by Jones (2015), on the right side, are more specific suggestions that might be effective to support first-year engineering students' perceptions of Empowerment. One remaining question is whether increasing students' perceptions of Empowerment actually leads to higher engineering-related motivational beliefs?

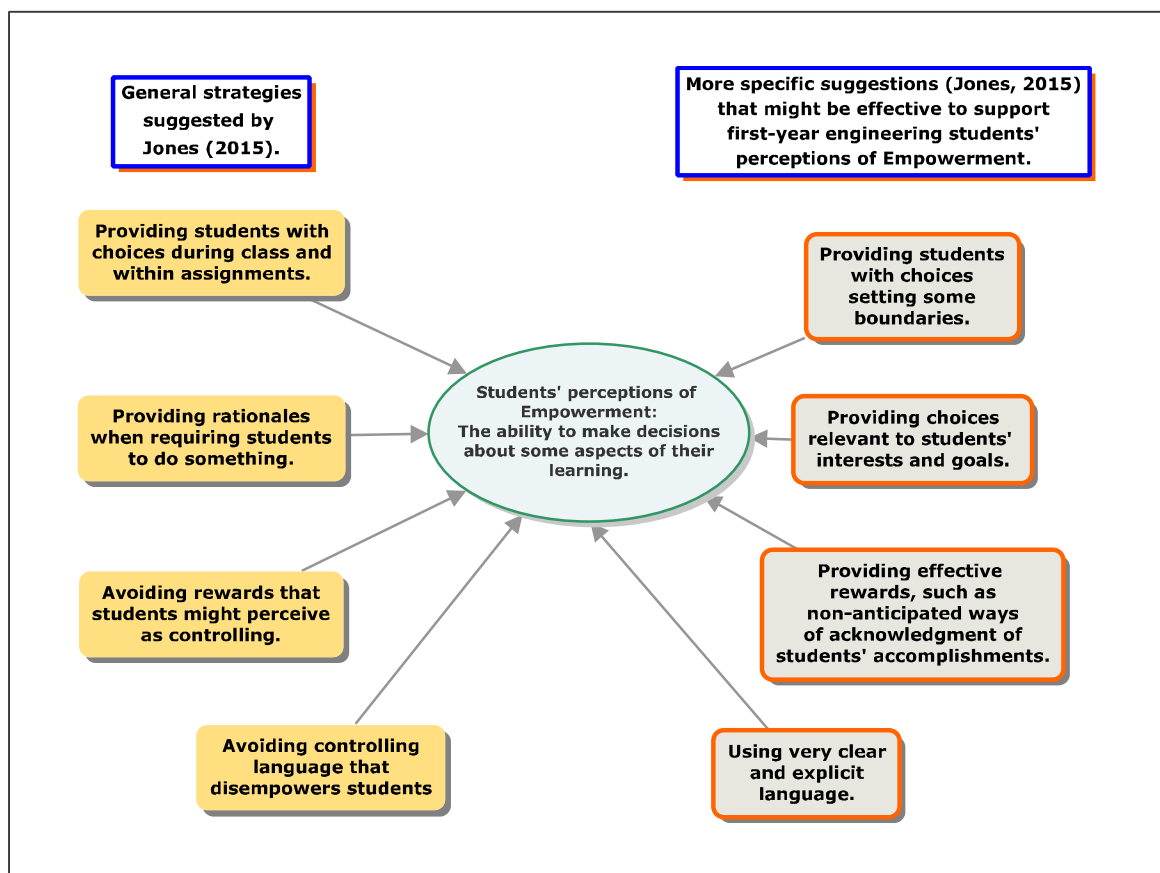


Figure 14. Empowerment Strategies Suggested by Jones (2015).

One explanation for the negative relationship between students' perception of Empowerment and engineering-related motivational beliefs might be that providing first-

year students with too many choices can overwhelm them. It may be that, while we understand that providing students with choices during class and within assignments, we should focus on providing students with choices but at the same time setting some boundaries (Jones, 2015) that might help to positively affect first year students' motivational beliefs. Additionally, first year engineering students might need choices that are meaningful to them. Katz and Assor (2007) suggest that choices are motivating when they are relevant to students' interest and goals; are not too numerous or complex and are aligned with students' values (Katz & Assor, 2007). While students may perceive some rewards structures as controlling, effective rewards might be necessary for freshman students. This idea aligns with the Success strategies described previously about providing feedback concerning if students are doing well or not in the class. One way to use effective rewards is by giving it as a non-anticipated way of acknowledgement of students' accomplishments (Jones, 2015). Finally, first year engineering students, especially during their first semester in college, might benefit from very clear and explicit language.

Whether these specific suggestions and strategies are ideal for first year engineering students will require additional research. However, in an attempt to understand how educational experiences in first year introductory courses affect students' engineering-related motivational beliefs, instructors and instructional designers might benefit from these suggestions when designing courses at the first-year level that support students' motivation to persist in engineering.

Finally, in terms of research, the findings of this dissertation add validity and evidence to the use of the MUSIC model of Academic Motivation to measure students'

perceptions of the courses and the use of the Motivational Expectancy-Value Beliefs constructs to measure students' engineering-related motivation. Based on the results of this dissertation, first year students' perceptions of Interest and Usefulness are not necessarily the same but they are closely related. I suggest these two constructs might be encompassed into a broader construct that includes perceptions of both something interesting and worth knowing for students. The example presented in this dissertation, provides a perspective on how to assess the effect of practices in engineering introductory courses and students' Expectancy-Value engineering-related beliefs. This dissertation, therefore, provides a research direction for the study about the relationship between first year engineering students' perceptions of Empowerment and their engineering-related motivational beliefs.

Although the generalization of the results is limited only to first year engineering students at this university, researchers can determine if they are likely to garner similar outcomes for their own student population by examining the characteristics of the courses, setting, and participants in this study. A main purpose of this study was to find practical solutions to problems encountered in introductory engineering courses. In addition, this study might be representative of courses included in institutions with different matriculation models, since research has suggested that the that content of first-year engineering courses is fairly consistent nationally (Chen, et al., 2013).

Future Directions

It is recommended that analysis with following cohorts with a large sample for the revised version of the course, which would increase the likelihood to detect existing differences in students' perceptions of the two versions of the course. In like manner, it is

recommended to incorporate qualitative data to better understand reasons behind the differences in students' perceptions. Given the differences in the two versions of the course, the similarities between students' perceptions of the class in terms of the Empowerment, Usefulness, and Interest components was unexpected. Additional research including other variables such as predominant classroom pedagogy, students' involvement and achievement, teaching styles is necessary for their role in explaining students' perceptions of the course.

Future research in comparing students' motivational beliefs could include other variables such as gender identification, ethnicity, and other background variables that were not included in this study; this could provide additional explanatory power to models explaining students' motivational beliefs. Disaggregation of data by instructors as well as by subpopulation could provide valuable information about the variety of outcomes. Another limitation of this work is that the survey is applied only at two points during the semester, at the beginning and at the end; intermediate surveys could give more information about trajectories in students' beliefs along the semester. In the same way, qualitative research could be beneficial since our data is reduced to numbers; therefore, students' voices about their own motivation may not be adequately represented and could help to better understand the necessary revision in curriculum and instruction.

It will be valuable to determine if the implementation of specific strategies based on the MUSIC model are more likely to support first year engineering students' academic motivation, and thus their engineering-related motivational beliefs. Further research could add to the models presented in this study with other variables that could provide more information in order to better understand how first year engineering students'

motivational beliefs are developed. Future studies incorporating qualitative research, such as verbal or written descriptions, could furthermore shed light upon our understanding regarding how students' perceptions of a particular course impact their motivational beliefs.

Reflections of the Researcher

Motivation is largely what makes us move by giving us the desire to adopt, maintain, direct specific behaviors. This aspect of human nature can be simplified: when we want to do something and we are motivated to do it, we are more apt to engage more productively in the activity. However, the reality is much more complex. Motivation is not a binary construct: students are not simply motivated or not motivated in our classrooms, they might be more or less motivated because of different factors at different times. As instructors, instructional designers, and researchers we keep striving to understand and determine which activities or experiences are likely to motivate our students to succeed, not only in the classroom, but also in their ensuing engineering careers. I realize from my own experience as a classroom instructor that sustaining students' motivation all the time is at best challenging but quite impossible. However, I also know that small details within the classroom, and slight actions from instructors can make a difference and can benefit first-year engineering students to remain excited about engineering. That was part of my goal with this study. I wanted to better understand how students perceived the courses, and how these perceptions could possibly affect their motivation related to engineering. I would then gain insight and have a clearer idea about how to design and facilitate engineering introductory courses.

Through teaching the new version of the course, the second time it was

implemented, and furthermore conducting this analysis, I experienced the challenges that come when trying to design and improve introductory courses. The experience of comparing the two courses taught me the importance of both informing our teaching and design practices in research, and assessing our practices with a purpose to improve student success. I believe that the expertise of each faculty can come together and create great things for students. I also believe that communicating research theories in plain and simple language will assist instructors who might not be familiar with research vocabulary to allow those instructors an opportunity to recognize their significance in the classroom. We are not just lecturers, instructional designers, or teachers, we can also impact a student's motivational beliefs, and the ensuing trajectory of his/her educational and career choices.

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Appendix A

Class and Workshop Activities and Assignments for Both Versions of the Course

Weeks	Course	Workshop	Class	Assignments
1	Revised	Product Archeology – Preparation (cell phone) /Course Introduction. Investigate Global, Social, Environmental, and Economic factors around the design a cell phone (student choice of cell phone). What impacted design, what impact did phone have.	Information Sources - College librarian presented on using the library, finding and evaluating sources, citing sources.	Product Archaeology Preparation Summary (Cell Phone)
	Standard	Workshop introduction Problem solving (hands-on)	Course Introduction: Attributes of the engineer 2020	Textbook problem
2	Revised	Product Archeology: Artificial Hip (Preparation phase) and Cell Phone (a simple text and talk phone) (Excavation Phase). Look into GSEE factors affecting form and manufacture.	Product Archeology: Follow up on Artificial Hip – investigating GSEE factors in class.	Product Archaeology Excavation Summary (Cell Phone)
	Standard	Teamwork Team building design activity (hands-on)	Introduction to design Engineering as a profession	Textbook problem How stuff works (HWS) team presentations Attend department information sessions
BOS SURVEY				
3	Revised	Engineering Careers – Job Skills and competencies. Discuss similarities across all fields, discuss common skills. Common Book discussion - opportunities.	Guest Speaker – Career Services. – what can career services do for students	Exploring Engineering Careers and Jobs Assignment/ Career Fair
	Standard	Sketching activity (hands-on)	Problem solving Sketching	Orthographic Sketching Textbook problems HSW team presentations ongoing
4	Revised	Data Analysis and Representation. Introduction to graphing – linear, exponential, and power.	Professional Engineering/ABET	Plotting

Weeks	Course	Workshop	Class	Assignments
		Graphing Basics, using data and graphing to estimate the value of parameter. Matlab: Introduction to vectors, Graphing	Data Acquisition/LEWAS LAB	
	Standard	Design Project introduction Graphing (hands-on)	Graphing	Plotting by hand HSW team presentations ongoing
5	Revised	Acquiring data – design an experiment to determine constant g. Available measurement system can measure distance and time. Can use pendulum eqns or eqns of motion. Mathematical Models Matlab: Script files	Algorithm Development and programming Loops and Decisions – translation of problem to flowchart to code	Gravity Experiment Preparation
	Standard	Design Project discussion Graphing/least squares linear regression activity (hands-on)	Graphing Linear Regression	Textbook problems Graphing basics Sustainable Energy Design Project (SEDP) HSW team presentations ongoing
6	Revised	Data Acquisition Arduinos and ultrasonic sensor Gravity Experiment – measure dist and time Analyzing data – parsing (using part of a vector)	Programming Max and Min Nested and stacked ifs .mat files	Programing Vectors Gravity Experiment Memos
	Standard	Mechatronics I (hands-on)	Problem Solving Mechantronics	Textbook problems Survey for each department information session SEDP Ongoing HSW team presentations ongoing
7	Revised	Line Following Robot – Getting to know the robot Communicating with the Robot	Programming Logic, decisions, logical operators Robot Algorithm Testing	Line Following Robot Algorithm
	Standard	Flowcharting (hands-on)	Sustainability Flowcharting	Mechatronic Assignment SEDP Ongoing HSW team presentations ongoing

Weeks	Course	Workshop	Class	Assignments
8	Revised	Robot Testing	Line Following Robot algorithm recap Review of Test 1	Line Following Robot Report
	Standard	No workshops this week	Problem Solving Ethics	Flowchart LabVIEW Tutorial SEDP Ongoing HSW team presentations ongoing
9	Revised	Problem Solving: Introduction	Teamwork Feedback Contracts	Concept Map Engineering Problem Analysis
	Standard	LabVIEW (hands-on) Ethics	LabVIEW programming	LabVIEW problems Course GVI SEDP Ongoing (Research Report) HSW team presentations ongoing
10	Revised	Problem Solving: Problem Definition Common Book	Team Roles. Teamwork Goals	Problem Formulation Memo Problem Formulation Concept map
	Standard	LabVIEW (hands-on)	LabVIEW Programming	LabVIEW problems: FOR loops SEDP Ongoing (Brainstorming Inventory, Team Evaluation 1) HSW Presentations ongoing
11	Revised	Problem Solving: Representations	Pathways Planner	Representations Memo Representations Concept map Pathway Planner
	Standard	LabVIEW (hands-on) LabVIEW DAQ (hands-on)	Intro to LabVIEW DAQ LabVIEW programming	LabVIEW problems: FOR loops SEDP Ongoing (Prototype Fair, Team Evaluation2) HSW Presentations ongoing
12	Revised	Problem Solving: Questioning – Claims/arguments Pathways Planner Exercise	No Lecture	Questioning Strategies Memo Questioning Strategies Concept map
	Standard	LabVIEW programming	LabVIEW Programming	LabVIEW problems: Case structures Gravity Experiment SEDP Ongoing
13	Revised	Problem Solving: Documentation – supporting/justifying Assertion Evidence Form	Technical Presentations Project Deliverables	Communication Memo Communication Concept map

Weeks	Course	Workshop	Class	Assignments
	Standard	LabVIEW programming	Design Project demonstration	LabVIEW game SEDPdemonstration (Presentation Materials) SURVEY
EOS SURVEY				
14	Revised	Problem Solving: Evaluation Presentation Expectations	Project Presentations Review of Test 2 /Exam notes	Final Concept Map
	Standard	Mechatronics II (hands-on) Workshop Wrap up	Globalization of engineering Practice & Study Abroad	Mechatronics II Assignment Final Report , Team Evaluation 3
15	Revised	Presentations	No class	Final Project Presentations
	Standard	No workshop	Course wrap up	