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

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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. Data were collected quantitatively through a pre-and-post survey with 1,037 (pre) and 1,056 (post) first-year engineering students at a research-intensive technical university. The work was framed by the Expectancy-Value Theory of Motivation. Results suggest that students' motivation decreases significantly over the first year in an engineering program, this aligns with the literature on engineering-related motivational beliefs. Similarly, our findings suggest that in the revised version of the course, the motivational constructs did not change which can be interpreted as an indicator that the new version of the course had a positive impact in mitigating drops in students' motivational beliefs. 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. We provide implications for research and practice.

Keywords: motivation; first-year engineering; expectancy-value; motivational beliefs

1. Introduction

Research suggests that motivational beliefs impact people's choice of whether to engage in a domain or a task [1]. Specifically, engineering-related motivational beliefs have been shown to predict career intentions, occupational choices, and overall success [2]. In view of the importance of students' success to increase the engineering workforce, understanding their 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 [3, 4]. For most students, engineering introductory courses are frequently the first exposure to the engineering profession. 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 compare students' Expectancy-Value engineering-related beliefs between two groups of students: those enrolled in a *standard* first-year engineering course versus those enrolled in a *revised* version of the same course designed, in part, to emphasize student motivation. More specifically, 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?

Motivational beliefs have been used to better understand how persistence occurs in engineering studies. The Expectancy-Value model developed by Wigfield and Eccles [5] is a useful framework to understand students' motivation and/or their choice to persist in 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 [4, 6–8]. However, achievement is known to be an insufficient predictor of persistence in engineering [9, 10]. 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 [11]

We need a better understanding of how to link pedagogical practices to students' choice to become engineers [12, 13]. It has become challenging to retain students when we have little understanding of students' goals, objectives, and decision-making criteria [11]. Hence, we need a better understanding

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of their beliefs and how to link pedagogical practices to students' choice to become engineers [12, 13]. Again, to enhance the overall engineering workforce, we need a better understanding of these choices.

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 Eccles' model, Expectancy-Value beliefs are shaped by many contributing factors: past experiences, socializers, and identity beliefs that are not included in this analysis [5]. 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 in these motivational beliefs by comparing students' motivational beliefs from the beginning to the end of the semester.

2. Role of introductory courses in engineering

During the last three decades, the engineering education community has strongly emphasized exposure to engineering for students during the first year in college [14]. 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 [15]. Since then, the inclusion of introductory engineering courses during a student's first year in an engineering program has grown nationwide.

Currently, introductory engineering courses are one common element in many first-year engineering programs even with different matriculation practices. According to Chen, Brawner, Ohland, & Kikendall [16], 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% of 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 to 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.

Still, current concerns about engineering retention and the preparation that engineering students require entail an examination of existing introductory engineering courses. Certain studies, for example, have suggested that students' motivation to persist in an engineering degree tends to decrease during the first year [17]. Thus, 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. In fact, numerous engineering programs have revised their approaches in first-year introductory courses in recent years, e.g., [18, 19]. Given the importance of these courses, 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.

3. Theoretical Framework: Expectancy-Value Theory

The Expectancy-Value model developed by [5] has been used to understand students' motivation and/or their choice to persist in engineering. Although several studies related to persistence in engineering are using motivational theories as a framework, most of them have studied the relationship between achievement and persistence [8, 20, 21]. However, achievement is known to be an insufficient predictor of persistence in engineering [22–24]. 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 [11].

The Expectancy-Value theory argues that students' performance, persistence, and task choice are all shaped by both their expectancy for success and values [5]. From an individual's point of view, expectancy beliefs describe the belief regarding the ability to do the task, whereas task-values clarify the importance of a task [25]. Eccles, et al. [5], 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 [26–28].

The *Expectancy* part of the model refers to individuals' beliefs about how well they will do on a task [29]. *Task 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 [5, 28]. Attainment refers to the value an individual attaches to participating in a task or the personal importance of doing well on the task [5]. Utility value refers to how useful or how well a required task is related to an 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 [5].

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 has 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 [24, 27, 28, 30, 31]. Both competence and value beliefs generally decrease with age [28, 32, 33]. In addition, changes in competence beliefs accounted for an associated decline in task values [32]; the combination of both high-self concepts and values suggests both as important to increase the likelihood of persevering and pursuing a career [34]. In a like manner, there is a strong relationship 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 their chosen field of study [5, 35]. In the same way, some studies have shown that youth's mathematics and science activity participation predicted their Expectancy and value beliefs [34].

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 of what these students' motivational beliefs endorse regarding the structure of courses and classroom practices in engineering. Eccles' [5] model presents a unique framework to help with this purpose.

4. Methods

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. Data were collected using the constructs involved in the Expectancy-Value model on 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. The study secured ethical clearance approval.

4.1 Context of the Course

This study compared two groups of first-year engineering students enrolled in two different versions of the same introductory engineering course. Both courses were offered during the same semester at the same university. 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 as a pilot 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. 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. 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.

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).

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

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

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.

4.2 Data Collection

We used data collected on Expectancy-Value by the engineering department where the two versions of the introductory engineering courses were offered. These items have been used to measure specific constructs related to engineering motivational beliefs [2, 17, 36]. All the items were rated using a 6-point Likert-type scale ranging from *strongly disagree = 1* to *strongly agree = 6*. The constructs included in this study were:

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., [17]). These items were based on scales used by Eccles & Wigfield [26] to assess students' expectancies in academic domains [17]. 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., [17]). These items were based on scales developed by [37] 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 [17]. 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., [2, 17, 36]). These items were based on scales developed by [38]. 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."

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.

4.3 Validity and Reliability

Jones et al. [17] established the validity and reliability of the constructs of the survey for first-year engineering contexts. Jones et al. [17] estimated the internal consistency reliability of the scales by calculating Cronbach's alpha. While the reliability and validity of this instrument in previous research contribute to the current validity and reliability of the survey, we examined construct validity. We conducted an exploratory factor analysis (EFA) and a confirmatory factor analysis (CFA) and demonstrated validity. In terms of internal reliability of the survey, Cronbach's alpha was also calculated.

4.4 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 engineering course at a large, research university in the United States. Two versions of the course were offered during the same semester to the same cohort of students. The course was redesigned with a goal, among other purposes, to "more effectively support student motivation to support retention" (unpublished internal document). The foundation of engineering course is a two-credit course with the goal of introducing students to the engineering profession, help them select their engineering major, and learn about teamwork, problem-solving, communication, and algorithmic thinking. The revised version was offered for the first time to approximately 25% of the incoming engineering students during the Fall semester. The revised version had a focus on solving ill-structured problems with an emphasis on skills that have been identified as transferrable, such as formulation, questioning, arguing, and evaluating, which were exposed as students worked on problems and had a high focus on teamwork. In addition, in the revised version students were presented with how engineers use data, with an accompanying requirement of modeling engineering systems. Both courses were offered simultaneously. Students were placed randomly into either version of the course, standard or revised. All students were emailed asking them to complete the survey that included a consent form. Tables 2 and 3 show participant demographics for the beginning of the semester (BOS) and end of the semester (EOS) surveys respectively.

Table 2. Participant Demographics Motivational Beliefs Survey (BOS)

Gender	Standard	Revised
Female	23% (197)	14% (26)
Male	76% (642)	86% (160)
Not Reported	1% (12)	0
Total	851	186

Table 3. Participant Demographics Motivational Beliefs Survey (EOS)

Gender	Standard	Revised
Female	23% (188)	15% (36)
Male	76% (620)	85% (204)
Not Reported	1% (4)	0
Total	812	240

4.5 Data Analysis

Descriptive statistics were analyzed to better understand data distribution and frequencies of the variables in the study. Inferential statistics also examined the possible statistically significant differences in students' engineering-related motivational beliefs at the beginning and the end of the semester for both groups of students. Data were analyzed using SPSS 24.0 software.

Before conducting the tests, a preliminary analysis was performed, which included: (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 not-normal data distribution. Since the data were non-normally distributed, nonparametric tests were used.

Two Wilcoxon signed-rank tests, which is the equivalent to a dependent t-test for non-normal data, were performed, one with the dataset at the BOS and one with the dataset at the end 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. Effect sizes were also calculated to demonstrate "the importance" of any differences since statistical significance can be affected by sample sizes [39].

4.6 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 a standard syllabus and lessons material that might have resulted in a similar way to teach the classes.

Second, the results of this study rely on self-reported data for all the variables. However, many researchers have established that self-reported data are a credible means of examining students' perceptions [38]. 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 a 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 [40] 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 [30]. Further research considering the inclusion of more items to better measure this construct is necessary.

5. Results

Because the data was not normally distributed, a Wilcoxon Signed-ranks test was conducted to compare the students' motivational scores in the *standard* version of the course at the beginning versus the end of the semester. The differences in scores were symmetrically distributed, as assessed by a histogram. Results of the test are presented in Table 4, p-values less than 0.05 were 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 the 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 [17].

In addition, we conducted a Wilcoxon Signed-rank test to compare the students' motivational scores in the *revised* version of the course at the beginning versus the end of the semester. Because the data was not normally distributed, a Wilcoxon Signed-rank test was conducted. The differences in the scores were symmetrically distributed, as assessed by a histogram. Results of the test are presented in Table 5, 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 the beginning and end of the semester.*

6. Discussion

In this study, data were compared from the beginning and the end of the semester for each version (standard vs. revised) of the course using Wilcoxon signed-rank test. This test is considered as the nonparametric equivalent to the dependent 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., [17]. In the *revised* version of the course, there were no statically significant differences in the three constructs between the beginning and the end of the semester. This finding is impor-

Table 4. Comparison of Motivational Constructs From Beginning to End of the Semester for the Standard course

Course	N	Construct	M (SD)	Mdn	Z	P-value (2-tailed)	Effect Size
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 a statistically significant difference.

Table 5. Comparison of Motivational Constructs From Beginning to End of the Semester for the Revised Course

Population (Course)	N	Construct	M (SD)	Mdn	Z	P-value (2-tailed)	Effect Size
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			

tant and must be interpreted according to its practical significance.

Attainment value refers to the personal attached to doing well on a given task [1]. This construct is considered similar to domain identification which is defined as the extent to which one defines the self through a role or performance in a determined domain [41]. 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 [5]. 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 [17]. 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 [39]. 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 [42]. 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 very difficult to control. However, the finding that there were no statistically significant differences for students' Expectancy-Value beliefs for this group of students encourages instructional designers and faculty to remain open-minded about a possible improvement in course development in the future. As instructors and course developers, this is 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 [36], 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 [43]. As instructors and instructional designers, we are in a unique position to implement these strategies informed by research that can have such an impact on the future engineering workforce.

The *revised* version of the foundations of the engineering course was intentionally developed to increase student motivation and support retention. Hence, some of the aspects of the course can be useful to administrators, instructors, or instructional designers looking for ways to improve Expectancy-Value engineering-related beliefs like expectancy, attainment, and utility. Changes in the *revised* version were grounded on existing literature, as well as the influence of experts in the engineering department. The *revised* version of the course was focused on problem-solving rather than design process instruction. Problem-solving 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. 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 a football helmet, obstacle avoidance robot, and hanging engine.

In the *standard* version of the course, *teamwork* was mainly part of one class, wherein the approach for discussion was primarily adapted from [44]. In contrast, within the *revised* version of the course, teamwork discussions were integrated throughout the course and emphasized in several classes, versus one class in the *standard* version. The *revised* approach to teamwork was adapted from [45] 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 included in the class discussions.

One notable difference regarding class 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 [46]. 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 terms of assignments, in the *revised* version of the course, students were asked to write several summaries, memos, reports and create several concept maps throughout the semester. 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 [47].

7. 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. Historically, ample evidence has shown that motivation can be a predictor of success and that motivation among first-year engineering students decreases through their first year of study. This study showed that expectancy, attainment value, and utility value decreased in both the original and revised course. However, while the drop in each construct was significant in the original course, the decrease in these constructs was not significant in the course which was redesigned. In this case, revising a course intentionally considering motivation mitigated the decrease in motivation. This information is of value to programs considering a revision of their curriculum to improve student motivation and success: revising a course with attention to motivational constructs may mitigate the expected decrease in student motivation.

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.

Future research could consider a longitudinal analysis of students' motivational beliefs. 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.

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Appendix A

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

Week	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. Graphing Basics, using data and graphing to estimate the value of parameter. Matlab: Introduction to vectors, Graphing	Professional Engineering/ABET Data Acquisition/LEWAS LAB	Plotting
	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
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 Evaluation 2) 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
	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	