

ADVANCING STUDENT MOTIVATION AND COURSE INTEREST THROUGH A  
UTILITY VALUE INTERVENTION IN AN ENGINEERING DESIGN CONTEXT

by

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## DEDICATION

There would be no way I could have accomplished this endeavor without the incredible support of my husband, Luke. Thank you for empathizing with my trials, supporting me in my successes, and being there for our children.

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## ABSTRACT

Student motivation is essential for academic success. Researchers and educators across broad educational spectrums have identified important factors effecting undergraduate student motivation. Understanding and improving student motivation is critical for educators to keep students engaged and motivated. Student motivation is multifaceted and complex with interest as one of many factors related to motivation and motivated behavior. Student interest in course material can be supported by helping them understand the value and relevance of the material to their professional goals.

This study uses expectancy-value framework to understand students' perceptions of the value and relevance of course material and how these perceptions influence interest and academic performance. One means for understanding perceived value is to assess the perception of the utility value, or the view of usefulness, of the task to their present or future goals. Educators can encourage value by asking students to write about the relevance of the course material to their life through structured utility value interventions. This study compared the performance, interest, and motivation between students who participated in structured utility value interventions and those in a control group who did not while enrolled in a third-year multidisciplinary engineering design course. Secondary research questions explored the effectiveness for low-performing students and the frequency at which connections were made. Students completed a survey at the beginning of the course and near completion of the course. Data was gathered during the initial semester of the COVID-19 pandemic.

Students' interest in the engineering design process and in the course material increased significantly for students writing to the utility value prompts. Perceived utility value was shown to be a significant predictor in student interest. Academic performance outcomes were not effected by participating in the intervention. Low-performing students did not experience benefit from the interventions.

This study builds on and extends previous research on the effectiveness of utility value interventions in impacting student interest and motivation within an engineering design context. Practical application of the results provides educators a simple, cost-effective tool for increasing student interest and motivation in engineering.

## CHAPTER ONE

### INTRODUCTION

In education the phrase “motivation, motivation, motivation,” is analogous to the real-estate phrase “location, location, location.” One of the most important levers educators have to improve learning is motivation (Olson, 1997). Motivation refers to what makes a person start a task, what keeps them moving, and what helps them finish a task. Motivation can be defined as the process whereby goal-directed activity is instigated and sustained (Pintrich, 2002). Motivated learners have increased attention to their learning, increased effort to learn a difficult task, increased persistence to achieve mastery of skills, and increased engagement with the choice of tasks (Zimmerman & Schunk, 2011), while unmotivated learners are apt to be more inattentive and not understand what is being taught (Zimmerman & Martinez-Pons, 1992).

Individual choice to participate and stay engaged on a task can be internally motivated (intrinsic) or externally motivated (extrinsic). Extrinsically motivated classroom strategies focus on rewards or punishments to encourage certain behaviors. These strategies imply that learning tasks are not satisfying and provide an external incentive for participation. Rewards have been shown to be weak reinforcers in the short term, have limited impact on performance, and reduce motivation to undertake similar tasks in the future (Benabou & Tirole, 2003). Alternatively, intrinsic motivation comes from within someone and is not related to outside sources. Intrinsically motivated students pursue tasks for personal satisfaction and not for rewards. Classroom strategies to

increase intrinsic motivation encourage student interest (Hidi & Renninger, 2006) and motivation (Deci & Ryan, 1985) to find enjoyment in their own learning. When students are interested in learning, they become more engaged, pay attention in class, and ultimately perform well (Renninger & Hidi, 2015).

One way to increase student interest in learning is for students to see value and relevance of the course material not only to satisfy short-term goals but to achieve long-term goals (Atkinson, 1958; Harackiewicz, Barron, Tauer, Carter, & Elliot, 2000). Students often struggle to see value in what they are learning and make connections to their future goals. Student perceptions of value in learning activities can be placed within an expectancy-value framework (Eccles et al., 1983) which suggests task performance perceptions are related to their perceived value in completing the task.

Recent research indicates classroom interventions can be applied to improve perceptions of value (Harackiewicz & Hulleman, 2010; C. Hulleman, Godes, Hendricks, & Harackiewicz, 2010; C. S. Hulleman, Kosovich, Barron, & Daniel, 2017). Hulleman and colleagues (C. Hulleman et al., 2010) used simple writing interventions prompting students to recognize the usefulness of the course material showing an increase in both interest and student performance. These studies support the effectiveness of reflective utility value interventions in science, technology, engineering, and mathematics (STEM) education but have not been directly applied to engineering courses (C. Hulleman et al., 2010; C. S. Hulleman et al., 2017; Kosovich, Hulleman, Phelps, & Lee, 2019).

Increasing intrinsic motivation for learning has shown to improve interest and performance in the classroom. Interest can be manipulated by helping students see value

and relevance in the course material. Utility value interventions can facilitate these connections in a purposeful way. The hope of this study is to investigate if it is possible to help students follow this path for them to realize educational benefits they may be missing.

### Study Objectives and Organization

The role of the researcher in the current study is very personal. As the researcher and instructor for a third-year multidisciplinary engineering design course, the same question has surfaced over and over, “Do students see value in the course material and are they making connections between the course content and their future as engineers?” Out of this question the quest began to examine if other educators had the same question and what they were doing to find the answer. Studies answering these questions frequently use expectancy-value framework to pair student perceived usefulness of a task and the value they see in completing the task. Writing interventions are commonly used in motivation research because they require relatively little classroom or student time and can be adapted to almost any course (Lazowski & Hulleman, 2016) .

The purpose of the study is to evaluate the efficacy of a simple motivation intervention that requires little class time for educators to increase student interest in the course material and performance in the course. The core research design used writing interventions to increase utility value of the class. A small pilot study was performed in Fall 2019 with the full study implemented during the Spring 2020 semester. A pre-test and post-test design allowed for specific metrics taken before and after the writing

interventions. Students were assigned to control and intervention groups based on their class.

The organization of this thesis is as follows. The Literature Review, Chapter 2, covers motivation theories within education and their application in engineering while emphasizing the chosen theoretical framework. Chapter 3 summarizes the Methods used in the study, explanation of the variables, and specifics of the sample population. The Analysis section, Chapter 4, addresses each research question and the study outcomes. Chapter 5, Results and Conclusion, provides a summary of the research and the contributions to the greater body of engineering education research along with recommendations for future work.

## CHAPTER TWO

## LITERATURE REVIEW

The literature review is situated by first reviewing general motivation theories applied to educational research with emphasis given to the selected framework for the current study, Expectancy-Value framework. The review illustrates the breadth of available theories within engineering education research. Next, the application of these theories in a STEM/Engineering context is evaluated along with an emphasis of expectancy-value theory within engineering. Then, specific motivation measures and assessment instruments are summarized to ground the current study in utility value interventions. Finally, the study is presented in the larger context of engineering education. Figure 1 outlines the strategy for the literature review.

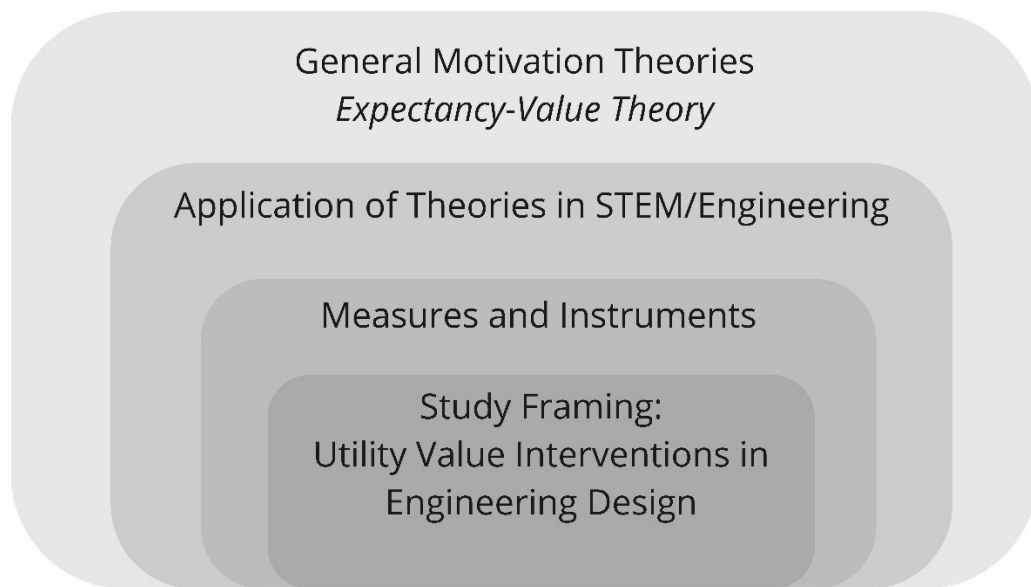


Figure 1: Literature review strategy.

### General Motivation Theories

Motivation is an urge to behave or act in a certain way that will satisfy one's goals or desires. The word motivation is derived from the Latin term 'movere,' meaning 'to move.' Motivation is an action to achieve goals or tasks. An individual's motivation can be generated from within (intrinsic) or from external sources (extrinsic). Intrinsic motivation is driven by internal rewards and results in a sense of autonomy, mastery and purpose. Extrinsic motivations are driven by external rewards or punishments. Extrinsic motivations are utilized in order to receive something or achieve certain behaviors from others.

Modern motivation theories consider an individuals' beliefs, values, and goals and how those translate into actions. To understand the breadth of current theories, Eccles and her colleagues (Eccles & Wigfield, 2002; Wigfield & Eccles, 2002) reviewed and grouped current motivation theories into four categories: 1) theories focused on expectancy, 2) theories focused on reasons for engagement 3) theories focused on integrating expectancy and value, and 4) theories integrating motivation and cognition. Several different theories are explained within each category. These categories are used to explore themes that promote the framework for the current study.

### Expectancy Theories

The concept of expectancy stems from an individuals' understanding of the difficulty of a task and their perceived ability to successfully perform it (Wigfield & Eccles, 2002). Self-efficacy theory and control theory are examples that fall within this category. Self-efficacy was first introduced by Bandura (1986), as part of a social

cognitive motivation model grounded in the perception of success or failure. Bandura defines self-efficacy as, “an individuals’ confidence in their ability to organize and execute a given course of action to solve a problem or accomplish a task” (Eccles & Wigfield, 2002, p. 110). People are more likely to engage in a task when they have a higher perception of self-efficacy. Bandura’s theory focuses on two kinds of expectancy beliefs: outcome expectations and efficacy expectations. Outcome expectations are the belief that specific behaviors will lead to specific outcomes (e.g. “If I study for this exam I will do well”). Efficacy expectations are whether the individual believes they can produce the behavior to generate the specific outcome. An individual can believe a certain behavior will produce a certain outcome (outcome expectation) but they may not believe they have the ability to perform the behavior and achieve the outcome (efficacy expectation). Control theory suggests that an individual should expect to succeed relative to their perceived feeling of control over success or failure (Crandall, Katkovsky, & Crandall, 1965). Connell and Wellborn (1990) expanded on this foundation and incorporated components such as competency, autonomy, and relatedness. They advocate when individuals feel in control of their achievement outcomes, they feel more competent.

### Engagement Theories

While the previous theories answer the question of “Can I perform the task,” they do not explain why people choose to engage in a task. Even if people believe they can perform a task successfully, they still need a compelling reason to do so. This aspect is addressed in task value theories. The theories in this category include self-determination

theory (SDT), interest theory, flow theory and goal theory. SDT suggests individuals are motivated by three psychological needs (Deci & Ryan, 1985, 2008). When needs for competence, relatedness, and autonomy are fulfilled then an individual becomes self-determined. The competence need is fulfilled when one has gained mastery of a new skill. The relatedness need is fulfilled by experiencing a sense of belonging and attachment to others. The autonomy need is fulfilled when one feels in control of their own actions and behaviors. These three needs direct intrinsic motivation and self-determined behavior. Flow theory argues that a person can become fully immersed in an activity when intrinsically motivated and having a clear set of goals and with paired intense focus. In goal theory, individuals are motivated to perform tasks when specific and clear goals are communicated. Goals can be generated by the individual or by someone else such as a teacher or employer.

Another category of engagement theory explores the concept of interest. Interest theories differentiate between individual interest and situational interest (Hidi, 2001). Most of the research on situational interest focuses on the characteristics of a task that generate personal interest. Individual interest has two components: feeling-related and value-related valences. Feeling-related valences refer to the feelings an individual associates with an activity such as involvement or stimulation. Value-related valences refer to the personal importance to an activity. Individual interest research may focus on the quality of learning such as deep-level learning compared to surface-level learning (Renninger, 1992).

### Theories Integrating Motivation and Cognition

The connection between motivation and cognition has interested many motivational theorists. One large body of research addresses how one self-regulates behaviors to achieve learning goals. A self-regulated learner monitors, directs and regulates action toward achieving goals, specifically academic goals. Self-regulation looks at the interaction between the person, their behavior engaging in the task, and the environment (Zimmerman, 2000). Zimmermann describes that self-regulated learners believe they can perform a task, set goals for themselves, and use a variety of self-regulated strategies to succeed.

Eccles and Wigfield (2002) also identify several other theories combining motivation and volition (Corno, 1993; Kuhl, 1987). One's volition, or strength of will, to complete a task can lead to action a persistence even in the face of distractions (Kuhl, 1987). Distractions can be overcome through cognitive control strategies (avoid distracting information), emotional control strategies (keeping emotional states in check), and environmental control strategies (constraining one's environment).

### Theories Integrating Expectancy and Task Value

A number of theories look at the intersection of a person's beliefs about their ability to perform a task with the value or importance they place on the task. The foremost theories include attribution theory, expectancy-value theory, and self-worth theory. Attribution theory (Weiner, 1980, 1985) focuses on how individuals interpret events and how it relates to their thinking and behavior. The theory assumes people try to attribute causes to behavior. These causal attributions determine subsequent

achievement endeavors and are key to motivation behaviors. The most frequent achievement attributions relate to ability, effort, task difficulty, and luck.

In his expectancy-value theories, Atkinson (1964) states behavior is motivated by the desire to meet or exceed a certain standard perceived by the individual. Eccles and colleagues (1983) expanded on Atkinson's original theory to develop the expectancy-value model of achievement-related choices. This model depicts the relationship expectancy-related and task-related values have on choice, performance, and persistence.

An additional theory that integrates expectancy-related and task-value related constructs is self-worth theory. Covington (1992) argues a person's ability is seen as a critical component of success, and inability a cause of failure. A person is motivated to establish and maintain a positive self-image through their ability to successfully complete a task. More specifically, in a classroom setting, a person needs to believe they are academically competent to think they have worth as a person. Since students are evaluated frequently in the classroom, it is key to maintain self-worth as a person to achieve academic success. Some students find it difficult to maintain these beliefs and develop strategies such as procrastination, not trying, and avoiding challenging tasks in order to avoid seeming to lack ability.

The expectancy-value theory of motivation was chosen for the current study because it provides a link between achievement performance and choice most directly to individuals' expectancy-related and task-related beliefs. According to the theory, individuals will choose to participate in tasks based on their belief of how well they will complete it and if they see value in it based on several factors covered below. This

relates to the overall purpose of the study by looking at student's choice to participate in an academic task as it relates to the value they see in completing it.

### Expectancy-Value Theory

Modern expectancy-value theory developed by Eccles and her colleagues (Eccles et al., 1983; Wigfield & Eccles, 2002) are based on Atkinson's (1964) expectancy-value model. Eccles theory suggests achievement related choices are motivated by two factors: *expectancy*, how probable a desired outcome is achieved through behavior, and *value*, how much the individual values the desired outcome. Thus, according to theory, students are more likely to engage in a task if they expect to do well and if they find value in participating in the activity. These choices can be influenced by both positive and negative task characteristics. Individual motivation for a task depends on perceptions of probability of success combined with the value for completing the task. Motivation is highest when both expectancy and value are at their highest as represented in the following relationship:

$$\text{Motivation} = (\text{Perceived chance for success in a task}) \times (\text{subjective task value})$$

Expectancies and values are directly influenced by performance and achievement-related choices as depicted in **Error! Reference source not found.** They also influence performance, effort, and persistence (Wigfield & Eccles, 2000). The two main constructs of expectancy and subjective task value are further explained along with the four subcategories for subjective task value: attainment value, intrinsic interest value, utility value, and cost.

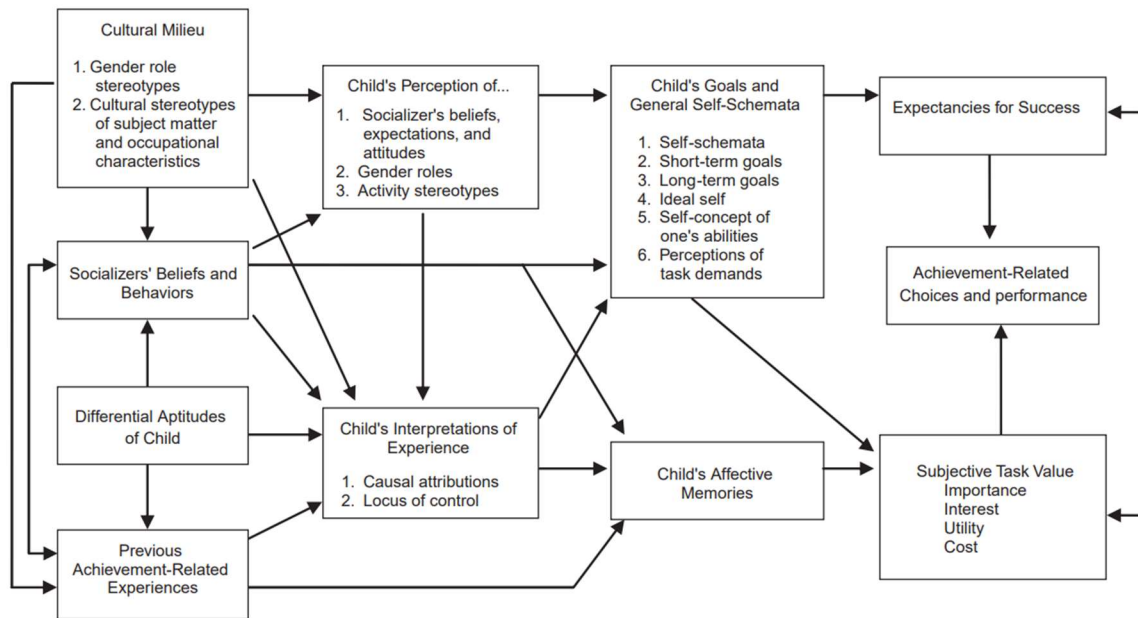


Figure 2: Eccles et. al model of expectancy-value (Eccles & Wigfield, 2002).

Expectancy for success is defined as an individual's belief about how they will perform in a task either immediately or in the future. For example, students might consider their expectancy to succeed when choosing to major in engineering. These expectations of success are shaped by long-term and short-term goals, self-concepts of abilities, perceptions of task demand, and previous achievement-related experiences. The expectancy belief is consistent with other motivation theories that emphasize self-efficacy (Bandura, 1997). Bandura notes efficacy expectations, one's belief that they can accomplish a task, rather than outcome expectations, the belief that a given action will lead to a given outcome, are a better predictor of performance and choice.

Subjective Task Value The second main construct in expectancy-value theory is the subjective task value. This construct generally refers to the 'values' one has toward specific tasks that influence their levels of persistence to engage and complete the task. If

one values the task, or has reasons to complete the task, they are likely to persist. The term subjective is used because the personal beliefs or the reasons to engage vary from person to person based on individual values. As an example, students may persevere to attain an engineering degree if they see value in achieving the goal.

There are four sub-constructs within subjective task value: attainment value, intrinsic value, utility value, and the cost associated with engaging in the task.

Attainment value is considered to be the importance one attaches to the task as it relates to their conception of their identity in a given domain. Students are motivated to attain goals because they are associated with perceptions of who they are, or their core values. Attainment value can be used to motivate students by making educational experiences meaningful for them.

Intrinsic interest value is the enjoyment one receives from participating in an activity. This value is similar to the intrinsic motivation construct discussed earlier. Students may value a task if it is enjoyable and interesting. It may not satisfy any future goals but brings satisfaction through participation.

Utility value is how well a task relates to current and future goals, including career goals. While one may not enjoy an activity, they may value the result it produces, intrinsic interest value. Students may not particularly enjoy taking certain classes, but they value the outcome they produce to achieve a future goal of becoming an engineer. Educators can tap into student motivation by being able to answer the classic question, “why do we need to know this?” The utility value and relevance of a task relates directly to an individual’s short-term and long-term goals (C. S. Hulleman, Durik, Schweigert, &

Harackiewicz, 2008). Since utility value focuses on the usefulness of task, it is possible to promote perceived value through external interventions (Harackiewicz, Rozek, Hulleman, & Hyde, 2012). Such interventions have been used by providing information about the utility value of a task (Durik & Harackiewicz, 2007) but also through having students write about the relevance of course material to their own lives (C. Hulleman et al., 2010).

The final component of subjective task value is the cost associated with participating in the task. Cost is realized as the negative aspects of engaging in a task such as the effort needed to succeed and the lost opportunity of not participating in a different task. When the cost of an activity is high, individuals may choose not to engage. Students may find the benefit of doing homework is not worth the cost of not doing other activities such as spending time with friends (Flake, Barron, Hulleman, McCoach, & Welsh, 2015).

#### Application of Motivation Theories in Engineering Education

To further inform and guide the current study, previous application and uses of motivation theories in engineering education were examined. Many of the articles in this literature review were chosen based on the commonality of linking some part of engineering education to possible career perceptions and goals. This is to emphasize the current research pathways and look towards possible future directions.

P. R. Brown, McCord, Matusovich, and Kajfez (2015) performed a systematic literature review on the motivation frameworks within in an engineering education context. The purpose of the review was to examine the use of motivation-related

research published in 71 journal articles from 2009-2012. One of the key outcomes was to understand how motivation is used in current engineering education research.

Findings suggest an inconsistent use of theory and motivation framework for a majority of the articles. Some do not have a defined framework, or they are inconsistent with their use. Connecting theoretical framework and prior research to existing work is key to progressing rigorous educational research (Borrego, Foster, & Froyd, 2014). A second finding reveals engineering education research tends to focus on only a few select set of theories. The most common theories used are self-efficacy, self-determination theory, and expectancy-value. Authors hypothesize these theories continued to be used due to prior research demonstrating the application and availability of tools for these theories.

Motivation research is becoming a mainstream focus within the American Society of Engineering Education (ASEE). The past four years have accounted for almost half of the total submissions related to motivation in engineering education in the past 11 years. The 2017 Annual Conference had dedicated sessions to motivation and engagement (ASEE, 2017). In these sessions, several articles addressed the use of projects or specific assignments to enhance student motivation (Butler & Bodnar, 2017; Jackson, Mentzer, Kramer, & Zhang, 2017; Rogers et al., 2017). Another paper presented a longitudinal study of how student motivational attributes and attitudes change over time revealed that student motivations are not static (Benson, McGough, Kuzbary, & Sharp, 2017). The study demonstrated motivations relating to future in engineering careers actually decreased over time and suggest students participate in specific activities and tasks that help them understand and envision their future goals as engineers.

A recent study assessed motivation, self-efficacy, and student engagement in an intermediate mechanical engineering design course (Ford, Ritz, & Fisher, 2020). The work suggests students need more opportunities to increase student motivation by making connections between activities and concepts to different courses. When students can link the usefulness of applying concepts to courses they are interested in, they feel motivated to invest effort into those classes.

#### Application of Expectancy-Value Theory in Engineering Education

Expectancy-value theory is also commonly applied in engineering education. P. R. Brown and Matusovich (2013) used expectancy-value theory to guide research on student persistence in pursuing an engineering degree. The framework provided a model to understand if students believe they have the characteristics needed for success in their given engineering field. The longitudinal study suggests students need help bridging the gap between the relevance of what they are learning in the classroom and what they will be doing as engineering in the future.

Expectancy-value theory was used in an analysis of first-year engineering students looking for relationship between expectancies, value, achievement and career plans (Jones, Paretto, Hein, & Knott, 2010). The major findings of the study revealed expectancy- and value-related constructs predict different outcomes. Expectancy-related constructs predict achievement and value-related constructs predict career plans.

Integrating these two constructs together can help students combine their educational experiences as they relate to future careers. Mamaril, Usher, Economy, and Kennedy

(2013) also found a positive correlation between expectancy and self-efficacy to academic achievement in engineering service courses.

Many of the studies reference the need for students to connect what they are learning to their future goals as a motivation strategy. Hulleman and colleagues (Harackiewicz & Hulleman, 2010; C. Hulleman et al., 2010; C. S. Hulleman et al., 2017) have used utility value interventions to make these connections in STEM courses. Using an expectancy-value framework, Hulleman (2010) hypothesized the implementation of a relevance intervention would encourage students to make a connection between a task and their lives to increase the perception of utility value for the task. Results indicate an increase in perceived utility value for a task translated to an increase in interest and performance. Perceived task value can stimulate engagement for students and facilitate the development of situational interest. The research design to implement the relevance (utility value) interventions include asking students to write a short essay describing the relevance of an activity to their current life or future lives. Motivation interventions have been shown to be effective for enhancing educational outcomes (Lazowski & Hulleman, 2016). Participants perceived utility value, interest in the task, and performance on the task were measured. Utility value interventions have been applied in various education levels such as middle school (Kosovich, Hulleman, Barron and Getty 2015) high school (Hulleman, Hara 2009), and undergraduate students (Grays, 2013, Hulleman 2008, Hulleman 2017). These interventions have also looked at performance based outcomes for low-performing students and explored the frequency at which connections are being

made (C. S. Hulleman et al., 2017). Based on the literature, this style of intervention has not been thoroughly applied in an engineering context.

This section concludes the discussion on motivation theories in engineering education. Table 1 summarizes the chosen framework of expectancy-value theory and reviews each of the constructs. The next section addresses specific assessment tools to measure these various constructs.

Table 1: Summary of constructs with Expectancy-Value Theory adapted from (Jones et. al, 2010).

<b>Constructs</b>	<b>Definition</b>
<i>Expectancy-related constructs</i>	
Expectancy	One's belief in the possibility of his or her success
<i>Value-related constructs</i>	
Attainment value	The importance of doing well in terms of one's core personal values
Intrinsic interest value	The enjoyment one experiences from engaging in activities, or the interest one has in activities
Utility value	The usefulness in terms of reaching one's short- and long-term goals
Cost	The effort required to pursue an activity and the tradeoffs

### Measuring Motivation in Engineering Education

Student's motivational beliefs have been of particular interest in both broad educational research and in engineering education research. Research studies have sought to understand and measure student's motivational behaviors through the creation of survey instruments grounded in expectancy-value theory (E. R. Brown, Smith,

Thoman, Allen, & Muragishi, 2015; Kirn & Benson, 2013; Pintrich, 1991). The following is brief summary of common validated instruments and their application within engineering education. The final model presented is the instrument deployed for the current study.

The Motivated Strategies for Learning Questionnaire (MSQL) developed by Paul Pintrich (Pintrich, 1991; Pintrich, Smith, Garcia, & McKeachie, 1993) seeks to assess students' motivation and learning strategies to support student learning and create a faculty informed response. Themes in the 81-item MSQL range from task value, self-regulation, time management, test anxiety and more. The instrument has been used in research studies from elementary students to secondary education (Duncan & McKeachie, 2005). While the tool has been widely used in its entirety, several subscales have been used in standalone versions. Harackiewicz et al. (2000) used the learning strategies subscales to inform predictors of interest and performance. These became some of the key items used in the current study.

P. R. Brown et al. (2015) identified a need to understand motivation constructs specifically within an engineering education context and developed an Engineering Motivation Survey. The survey development was based on other validated instruments within an expectancy-value framework. Survey measures consider interest, attainment value, utility value, expectancies, and cost. Initial results indicated the survey items could be used to study student motivation relating to obtaining an engineering degree and achieving future career goals.

The Motivation and Attitudes in Engineering (MAE) measure was developed to assess students' attitudes related to their engineering education. The survey is grounded in Expectancy x Value Theory, measuring three motivation constructs: expectancy, attitudes about present tasks/goal, and attitudes about future tasks/goals. This instrument has been applied to study persistence in engineering by addressing long-term and short-term goals (Kirn & Benson, 2013; Kirn, Morkos, & Benson, 2012).

The Engineering Student Motivational Beliefs Scale, (ESMBS) uses expectancy-value theory and seeks to incorporate the cost constructs by adding the quantification of costs to understand student's expectancies and perceived values of completing an engineering degree (Panizo et al., 2015). In the 12-item instrument, three items refer to expectancy, three items refer to value (attainment, utility, and interest) and three items refer to cost (loss of values alternatives, effort related to engineering, effort not related to engineering, and psychological cost). A three-phase approach was carried out to validate the instrument with preliminary validate results showed support for the internal consistency of the items while raising concern for others. Authors indicated further research with a large sample a size was need for validation.

Many of the validated instruments within expectancy-value theory extend the original constructs developed by Eccles and combine them with other constructs or in other STEM areas (Jones et al., 2010; Perez, Cromley, & Kaplan, 2014). Perez et al. (2014) collected data over a broader STEM population to incorporate identity development within expectancy-value theory while also focusing on the cost component. Path model analysis of the 32-item survey suggested an excellent model fit and indicate

identity development is important aspect of student's perceived value of remaining in STEM and the costs associated with it.

Panchal, Adesope, and Malak (2012) and colleagues used expectancy-value theory to understand student perceptions of the effectiveness of an engineering design project. The authors created a 30-item instrument with 9-items relating to expectancy, 9-items relating to value, and the remaining items given to structure of the project and learning outcomes. The survey provides instructors a quantitative tool to evaluate design projects rather than using judgement alone.

Based on prior research (C. Hulleman et al., 2010); C. S. Hulleman et al. (2017) used a self-report survey to quantify expectancy, utility value, cost, interest, and connection frequency measures used explicitly with utility value interventions. The 25-item scale used an eight-point Likert scale to evaluate motivation measures. It has been previously validated and applied in educational levels from middle school to secondary education and in STEM and non-STEM applications. The current study replicates the use of the instrument in an engineering design context.

### Study Framing

A review of the literature recognizes the breadth of motivation theories within education and specific applications to engineering education. Expectancy-value theory has been applied throughout engineering education to seek answers regarding student motivation across a variety of applications. While that field is very broad, specific examples emphasize students making connections with the relevance of education tasks

to their future career goals. The literature shows motivation can be enhanced when students see value and relevance in their current studies.

Increasing student motivation is linked to increasing interest and perceived utility value of tasks. Utility value centers on the usefulness of performing the task to achieve future goals. When students believe what they are learning is useful, they are more likely to be interested in the topic. (C. S. Hulleman et al., 2008) Other studies have shown value as way to increase utility value is through self-reflection (Harackiewicz, Canning, Tibbetts, Priniski, & Hyde, 2015). Utility value interventions have been applied in many areas but have not been explicitly explored in an engineering design context.

Using these findings, the focus of this work is to further confirm the use of utility value interventions as a simple way for instructors to increase motivation through promoting the utility value of the course content. Written utility value interventions have been used in previous studies as a way for instructors to provide a simple means to increase meaning and value of a course. Additionally, utility value interventions can be particularly effective for students with low-performance expectations (C. Hulleman et al., 2010; C. S. Hulleman et al., 2017).

## CHAPTER THREE

## METHODS

This chapter presents the research methodology employed in this quantitative study into the usefulness of utility value interventions. Experimental research design utilized a treatment and control group to assess differences between the groups. Survey research tools were used to measure key outcomes of interest and frequency of connections while graded assignments were used to measure performance. The remainder of this chapter walks through the details of these methods.

Research Questions and Measures

This study explored the relationship between participation in utility value interventions and the impact on students' interest and performance in a required third-year multidisciplinary engineering design course offered at Montana State University. The course introduces project management, teamwork, and leadership with the primary focus of the course dedicated to teaching engineering design process.

Research questions guided the study development and informed the researcher on data collection and analysis procedures. The questions are organized in three main areas. The first area explored how utility value interventions affect student interest and performance. The second area explored differences for low-performing students. The last group of questions looked for any significance with the frequency of connections students are making in the control and treatment groups as well as students who are closer to graduation. Table 2 provides the research questions by three themes.

Table 2: Research questions.

<b>Reference</b>	<b>Theme</b>	<b>Questions</b>
RQ1(a)	General	Does a utility value intervention affect student interest in a multidisciplinary engineering design course?
RQ1(b)		Does a utility value intervention affect student performance in a multidisciplinary engineering design course?
RQ2(a)	Low-performing students	Do utility value interventions impact low-performing students' interest differently than other students?
RQ2(b)		Do utility value interventions impact low-performing students' performance differently than other students?
RQ3(a)	Frequency of Connections	Do utility value interventions increase the frequency at which students connect course material to their future careers?
RQ3(b)		Do utility value interventions increase the frequency for students closer to graduation to connect course material their future careers?

These questions are answered using several distinct measures. Each of the measures came from one of three different sources: self-reported measures through surveys, demographic data provided by the Office of Planning and Analysis, and assignment grades provided by instructors. All data was clearly categorized in three ways to aid in organization of analysis: demographic variable, independent variable, or dependent variable. Table 3 summarizes the data structure for the study.

Table 3: Summary of study variables.

<b>Demographic Variables</b>	<b>Independent Variables</b>	<b>Dependent Variables</b>
ID Number	Treatment condition	Interest
Gender	Expectancy	Performance
Age	Utility value	Frequency of connections
Discipline	Cost	
GPA	Low-performing	
Instructor	Time to graduation	
Class		

Each of the independent and dependent variables were aligned to certain research questions. The structure in Table 4 helped the researcher organize and plan data collection. It was critical to have each question clearly defined and mapped to the variables when approaching the analysis phase.

Table 4: Research questions aligned with independent and dependent variables.

<b>Independent Variables</b>	<b>Dependent Variables</b>	<b>Questions</b>
Treatment condition Motivation measures	Interest	RQ1(a): Does a utility value intervention affect student interest in a multidisciplinary engineering design course?
Treatment condition Motivation measures	Performance	RQ1(b): Does a utility value intervention affect student performance in a multidisciplinary engineering design course?
Low-performing students Treatment condition Motivation measures	Interest	RQ2(a): Do utility value interventions impact low-performing students' interest differently than other students?
Low-performing students Treatment condition Motivation measures	Performance	RQ2(b): Do utility value interventions impact low-performing students' performance differently than other students?
Treatment condition	Frequency of Connections	RQ3(a): Do utility value interventions increase the frequency at which students connect course material to their future careers?
Time to graduation Treatment condition	Frequency of Connections	RQ3(b): Do utility value interventions increase the frequency for students closer to graduation to connect course material their future careers?

Note: Motivation measures are expectancy, utility value, cost.

### Course and Study Design Implemented

The course used in the current study concentrates on teaching engineering design process while incorporating other concepts such as project management, teamwork, and leadership in a multidisciplinary environment. The curriculum is designed around project-based learning allowing instructors to teach the main phases of the design process: Discover Phase, Define Phase, Ideate/Prototype/Test Phase. Third-year students are placed in multidisciplinary groups of three to five students to work through a semester long engineering design problem given by instructors. The main learning objective for the course is to work through the design process in a tangible way while learning to work in multidisciplinary environment. The course is required for all students in the College of Engineering to fulfill several ABET requirements such as working in a collaborative multidisciplinary team to learn engineering design and project management skills. The 15-week course averages 300 students per semester with class sizes limited to 40 students. Phases of the design process are presented sequentially and align with specific individual and group deliverables. For the current study, utility value interventions were conducted at the end of the first three phases of the design process: Discover, Define, and Prototyping.

The study design is based on experimental research protocols with pretest-posttest methods to examine the effects of a utility value intervention on student interest and performance in the course. All participants were administered the same pre-test survey. Following the pre-test, the treatment group participated in three utility value interventions while the control group experienced an assignment of similar duration, without the focus

on utility value. Both groups were administered the same post-test. The items measured in the pre-test were expectancy, utility value, cost and interest. The post-test survey measured the same items and added frequency of connections. Figure 3 represents the study timeline along with the measures taken for the pre-test and post-test and the timing of individual performance assignments.

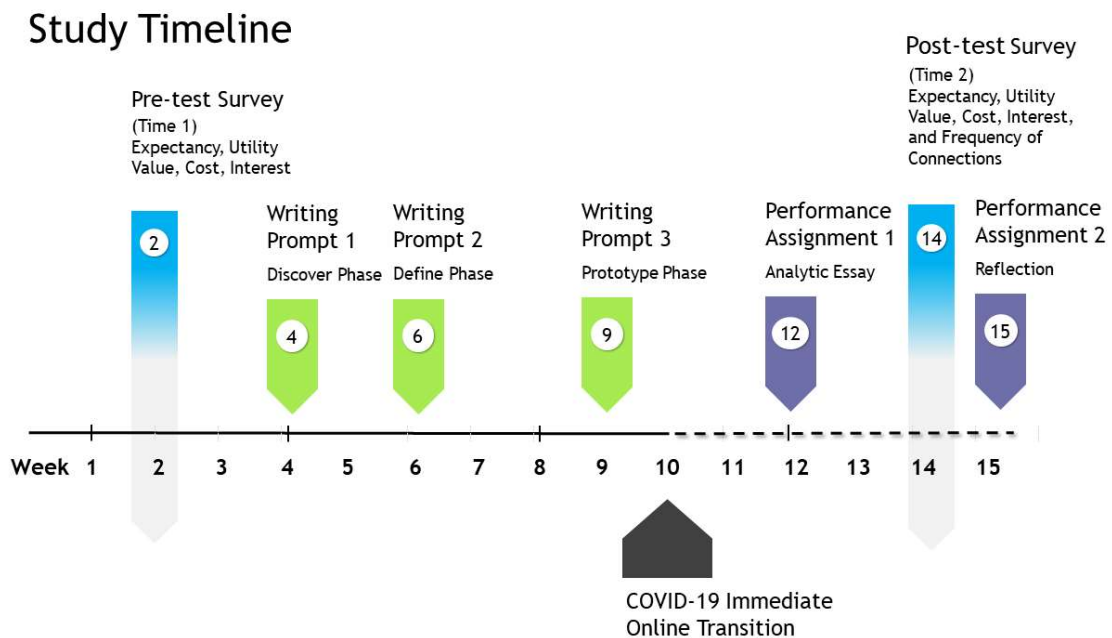


Figure 3: Detailed study timeline.

### Procedure

Study participants were asked to complete the pre-test survey and supporting demographic information through Qualtrics during the second week of class. Ten minutes of class time was allotted to complete the survey which was available to take for one week. During the 4<sup>th</sup> week of the semester, students completed the first writing

prompt corresponding to the Discovery Phase of the design process. The writing prompts were provided as a PowerPoint slide for the class. Handwritten responses were collected after 10 minutes. Study participants were encouraged to be as complete as possible during writing time. Those not present during the class writing time were asked to make-up the writing assignment. Participation credit was awarded for submissions. This procedure was repeated during the 6<sup>th</sup> week of the semester (completion of the Define Phase) and the 9<sup>th</sup> week of the semester (completion of the Prototype Phase). At the completion of Week 9, the university unexpectedly transitioned all courses to an online platform for the remainder of the semester due to COVID-19. Each of the in-class writing interventions were completed before students began online instruction.

Due to the exclusive online-only learning environment after Week 10, participants were asked to complete the post-test survey at home on their own time during Week 14. Participants were strongly encouraged to participate in the survey though no class credit was given. Only those who completed both surveys are included in the study analysis.

### Participants

Participants were chosen for the study based on enrollment in Spring 2020 of a 15-week multidisciplinary engineering design course at Montana State University. In the Spring of 2020, the course was taught over eight sections with four different instructors each teaching two sections. Total enrollment for the course was 352 students. Four of the eight total sections were involved in the current study with a total student enrollment of 176. The four sections were selected based on instructor availability. Of the students enrolled in the four sample sections, 138 completed both surveys (78% response rate) and

interventions. These students are the study sample. Study sample participants are referred simply as “students” in Chapters Three, Four and Five.

The allocation of treatment and control groups were chosen to balance several factors of interest. First, Class A was selected for the treatment intervention due to the incoming average GPA of the class. Second, to balance out the non-equivalence of groups and limit the possibility of instructor bias, each instructor had one treatment and one control group. Third, Class D was chosen for the treatment group to minimize the effect an instructor may gain by teaching the course material a second time.

Each class received the same intervention. This had the added benefit of the instructor providing only one intervention prompt per class period. Table 5 shows a summary of the four classes, time frame, sample size and average GPA for each class.

Table 5: Experiment design.

Group	Time	<i>n</i>	Intervention	Instructor	Average GPA
Class A	8:00	29	Treatment	1	3.19
Class B	9:00	37	Control	1	3.50
Class C	10:00	37	Control	2	3.36
Class D	11:00	35	Treatment	2	3.33

### Intervention Prompts

Three different times during the semester students were asked to write to their specific prompt after the completion of a given milestone in the design process. See Figure 3 for writing prompt scheduling during the semester. The control group participants received the following prompt: “In the space below, summarize what you know about the Discover Phase of Engineering Design Process in 3-4 paragraphs. We are not asking you to elaborate on the material, just to summarize the information that

you can recall.” The utility value treatment group received the prompt: “In the space below, write in 3-4 paragraphs how the material you have been studying in the Discover Phase of the Engineering Design Process relates to your future career. We are not asking you to summarize the material, just to elaborate on its relevance to your future career.” These prompts were adapted from previous utility intervention studies (C. Hulleman et al., 2010; C. S. Hulleman et al., 2017). These prompts were repeated during Week 6 and Week 9 for the two other phases of the design process. See Appendix A for a complete list of writing prompts for each phase.

#### Ethical Concerns and Institutional Review Board

A top priority throughout the study was ensuring ethical considerations were kept in mind. Following the procedures and methods outlined in the chapter substantiates the validity and reliability. Institutional Review Board (IRB) exempt approval was obtained before the pre-test survey was administered. The application approval (ST010920-EX) and consent forms are in Appendix B. In the first item of the survey, students consented to participate in the research along with the last four digits of their student ID number. The four digits of the ID number was used to match responses from the two surveys and to the additional data from the Office of Planning and Analysis. Data from all sources were compiled and formatted for use in the statistical program Minitab. Any identifying student information was removed after all data was compiled.

No grade item was associated for participating in the survey. Participation credit was given to students completing the writing interventions. The risk to participants were minimal and if anything could have potential benefits by spending time thinking about

the survey questions. Confidentiality was ensured once all data was matched by only using the last four digits of student ID numbers.

One key consideration was ensuring fair treatment of which classes would receive the control prompt, and which would receive the treatment prompt. It was decided the earliest section, 8:00 am, would receive the treatment condition. Based on previous semester data, the 8:00 section has the lowest average grade. To reduce any potential disparate treatment, it is intended to use any effective interventions in all sections going forward.

### Data Collected and Measured

#### Response/Dependent Variables

The three main dependent variables in the study are interest, performance, and frequency of connections. Interest and frequency of connections measures were provided by the students directly from the survey responses. Performance measures were provided by instructors from graded assignments. Each variable is explained more in depth.

Interest Outcome Interest in the course was measured on a 10-item scale (e.g. “I think the engineering design process is very interesting. I am excited about this class,”). Participants responded to survey items using an 8-point Likert scale that ranged from 1 (completely disagree) to 8 (completely agree). See Appendix C for a complete list of survey items. The interest measures were taken during Week 2 and Week 14. For analysis purposes, interest was treated as a continuous variable, a common practice in the literature (Jamieson, 2004). In alignment with other motivation intervention studies

(Lazowski & Hulleman, 2016), self-reported interest was used as a dependent variable. The self-report measure employs the use of rating scales, such as Likert-type questionnaires, to identify different levels of interest.

Performance Outcome The second dependent variable is course performance, which is also consistent with existing research in motivation interventions (Lazowski & Hulleman, 2016). Course performance was measured using two individual assignments during the semester. The first assignment was an analytical essay students wrote about a case study of their choosing. The second assignment gauging course performance was another individual assignment asking students to recap their design process experience. Both assignments were graded using a rubric provided in Appendix D. Assignments were graded on a scale from 0-100. The rubric was created to ensure consistency and inter-rater reliability (Hicks & Diefes-Dux, 2017; Oakleaf, 2009). Rubrics also provide students the category and level of competency they are being evaluated by. Several assignments were graded by both instructors. Differences in the rubric levels were discussed to ensure both instructors were grading for the same quality. Conversations pertaining to discrepancy in grading occurred until consensus and consistency were achieved. A composite performance metric took an average of both assignments.

Connection Frequency One of the key research questions seeks to understand if students are making connections between the course material and their future careers. This measure, connection frequency, was measured using a 3-item scale (e.g. “During a regular class period or lecture, how often do you connect the class material to your future career?”). Participants responded to survey items using a 6-point Likert scale that

ranged from 1 (never) to 6 (all of the time). The frequency of connection measure was taken one week before the end of the semester during Week 14.

#### Predictor/Independent variables

The main independent variable for the current study is the treatment condition of completing the utility value intervention (treatment group) or not completing the intervention (control group). This independent variable captures whether students write to the summative response (control) or to the more reflective prompt (treatment). Method of instruction, learning environment, and length/frequency of treatment remained the same. These controls are ensured by utilizing four sections of the same course taught in the same semester without varying curriculum or timeline.

A three-item measure was used for student motivation. The three items used to measure motivation were expectancy, utility value, and cost, as applied in previous studies (C. S. Hulleman et al., 2017). Expectancy was measured using a 4-item scale (e.g. “I am confident that I will be successful in this class”). Utility value was measured using a 6-item scale (e.g. “The course material is relevant to my future career plans”). Cost was measured using a 5-item scale (e.g. “I am unable to invest the effort that is needed to do well in this class”). Participants responded to survey items using an 8-point Likert scale that ranged from 1 (completely disagree) to 8 (completely agree). See Appendix C for a complete list of survey items. These measures were taken during Week 2 and Week 14.

Two of the research questions involve identifying low-performing students and comparing how their interest and performance levels change relative to other students.

Low-performing students were identified using incoming GPA data provided from the Office of Planning and Analysis. The mean GPA for each major was determined along with corresponding standard deviations. Low-performing students were identified as having a GPA one standard deviation below the mean for their specific major similar to other studies (Aiken, West, & Reno, 1991).

Participants were asked to self-report age, gender, discipline and expected graduation date when taking the survey for the first time. Table 6 indicates the possible responses and measures for each item.

Table 6: Dependent and Independent variables with response options.

<b>Variables</b>	
<b>Dependent Variables</b>	<b>Response Options</b>
Interest in Design	Likert 1-8
Interest in Class	Likert 1-8
Frequency of Connections	Likert 1-6
Performance in Course	0-100
<b>Independent Variables</b>	<b>Response Options</b>
Intervention Group	Control, Intervention
Expectancy Measure	Likert 1-8
Utility Value Measure	Likert 1-8
Cost Measure	Likert 1-8
Low-Performing Students	0, 1 (GPA below one Standard Deviation)
Birth Year	Year (4-digit)
GPA	4-point Continuous Scale
Gender	Male, Female, Other
Discipline	Bio Resources, Environmental, Civil, Construction Engineering Technology, Computer Engineering, Computer Science, Electrical, Industrial, Mechanical, Mechanical Engineering Technology
Expected Graduation Date	Spring 2020, Fall 2020, Spring 2021, Fall 2021

### Analysis Plan

Raw data was collected from the various sources and centralized in Minitab. Data was cleaned, recoded, and composite variables were calculated for analysis purposes. Analysis began by looking at initial descriptive statistics including cross-tabulations, correlations and test of normality. Factor analysis confirmed the loading of survey questions to the appropriate factor and led to other discoveries. Independent and dependent t-tests were used to examine difference within groups and between groups to answer many of the research questions. Linear regression analysis used the motivation measures to identify significant predictors to interest and performance. Figure 4 describes the analysis plan in more depth.

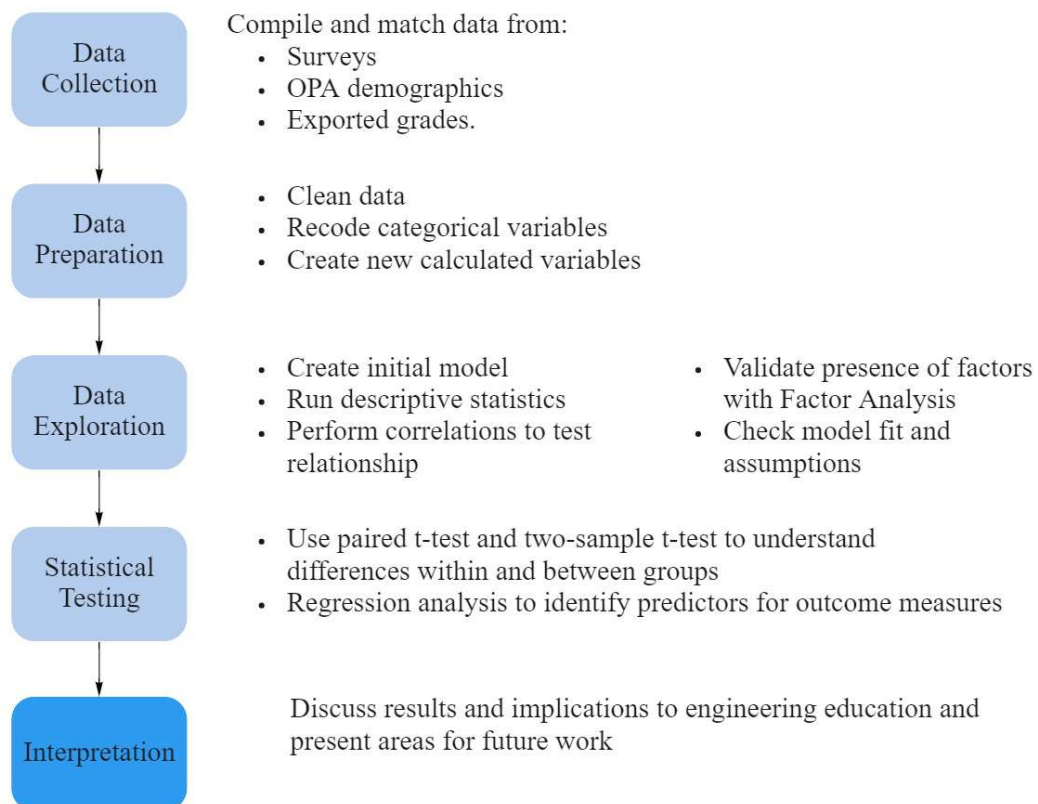


Figure 4: Analysis plan.

## CHAPTER FOUR

## ANALYSIS

The analysis section describes the approaches used to analyze the data and answers the research questions. The various sources of raw data were collected and compiled into one principal model in Minitab. The initial steps of cleaning, coding, and calculating composite variables allowed all the data to be standardized across the measures. Next, descriptive statistics and correlations provided an overview of the data and factor analysis provided validation of the intended constructs. Each research question was addressed through appropriate tests including two-sample *t*-tests, paired- *t*-test, linear regression and other methods.

The structure of the analysis section begins with general demographic information of the participants. Following demographics, instrument performance is examined by evaluating correlations between the measures and examining factor analysis results to confirm the presence of the intended factors along with addressing model fit and assumptions. Then the three main research questions are then addressed: first by looking at the study sample group to determine the effect of the utility value interventions on interest and performance in the course within the study sample; second looking at the same outcomes specifically for low-performing students in the study sample; third, the frequency at which students are connecting the course material to their future careers was explored.

### Demographics

General demographic information of age, gender, discipline, and graduation date were collected through the self-reported survey, this was matched with Office of Planning and Analysis data on incoming overall GPA data for each student. Of the students included in the study, 74 were in the control group (54%) and 64 were in the treatment group (46%). Table 7 summarizes demographic information by control and treatment groups.

Table 7: Comparison of demographic measures for treatment and control groups.

<b>Variables</b>	<b>Control</b>	<b>Treatment</b>	<b>Total</b>
Number of students	74	64	138
Low-Performing Students	27	26	53
Mean age in years	22.3	22.6	22.5
Mean GPA	3.43	3.27	3.35
Male	51	49	100
Female	23	15	38
Discipline			
CET/MET	3	5	8
Chemical Eng.	19	7	26
Civil Eng.	14	8	22
Computer Eng.	2	5	7
Computer Science	5	3	8
Electrical Eng.	7	6	13
Industrial Eng.	2	4	6
Mechanical Eng.	22	26	48
Graduation within 1 year	57	46	103

### Initial Analysis

The study raw data came from three different sources which needed to be combined, cleaned and standardized. Data from each source used the last four digits of a student ID number to match all responses. Most of the raw data was collected from the

pre-test and post-test surveys including demographic information. Additional data from the Office of Planning and Analysis provided GPA information. The third source contained exported grades from the university learning management system for the two performance measures, completion of the writing interventions, and class designation from the university learning management system.

New variables were calculated to provide mean values for expectancy, utility value, cost, interest and frequency measures. The new variables (e.g. Expectancy Mean, Utility Value Mean) were created for each of the outcome variables. These were done for both Time 1 and Time 2 measures. Table 8 summarizes the measures for both the control and treatment groups along with standard deviations, normality tests for skewness and kurtosis. It should be noted the performance measure does not fit with the cutoff criterion for skewness and kurtosis. This is addressed later in the analysis section.

Table 8: Descriptive statistics by experimental condition for major variables.

		Control (n = 74)				Treatment (n = 64)			
		<i>M</i>	<i>SD</i>	<i>Skewness</i>	<i>Kurtosis</i>	<i>M</i>	<i>SD</i>	<i>Skewness</i>	<i>Kurtosis</i>
Time 1	Expectancy	6.94	0.97	-1.00	0.81	7.12	0.93	-1.30	1.34
	Utility Value	6.00	1.25	-0.36	0.49	6.30	0.97	-0.16	-0.59
	Cost	3.61	1.27	0.34	0.26	3.50	1.31	0.09	0.43
	Interest in Design	5.51	0.72	-0.14	-0.26	5.59	0.79	-0.43	0.05
	Interest in Class	4.92	0.98	0.08	-0.51	5.36	0.94	-0.17	-0.97
Time 2	Expectancy	6.95	0.97	-0.61	-0.19	6.99	0.99	-0.75	-0.36
	Utility Value	5.71	1.32	-0.51	-0.30	6.11	1.22	-0.32	-0.61
	Cost	4.03	1.28	0.37	0.56	4.03	1.50	0.48	0.09
	Interest in Design	5.34	1.27	-0.13	0.07	5.92	1.24	-0.49	0.21
	Interest in Class	4.53	1.49	-0.51	-0.05	5.17	1.58	-0.98	0.83
	Frequency	3.25	0.95	0.29	-0.54	3.46	1.04	0.00	-0.63
	Performance	0.90	0.15	-3.90	17.31	0.88	0.12	-2.60	6.71

### Descriptive Statistics

Additional descriptive statistics were calculated on the Time 1 and Time 2 measures. Means, standard deviations, and Cronbach's alphas were used to measure internal consistency of each construct (expectancy, utility value, etc.). The scale used to measure each of the constructs had a high level of internal consistency as determined by Cronbach's alphas ranging from 0.85 to 0.94, see Table 9 for specific values (Hair, Black, Babin, Anderson, & Tatham, 1998).

Table 9: Descriptive statistics for Time 1 and Time 2 data.

Construct	Time 1			Time 2		
	Mean	SD	Cronbach's $\alpha$	Mean	SD	Cronbach's $\alpha$
Expectancy	28.09	3.80	0.90	27.93	3.90	0.91
Utility Value	36.91	6.81	0.92	35.68	7.76	0.93
Cost	17.75	6.45	0.85	20.20	6.92	0.87
Interest in Design	29.45	5.80	0.92	28.06	6.30	0.91
Interest in Course	26.30	6.90	0.91	24.11	7.85	0.94

### Correlations

A Pearson's product-moment correlation was run to assess the strength and direction between the independent continuous variables in Time 1 and Time 2. This method is used for normally distributed, continuous data to measure the strength of a linear association between two variables (Schober, Boer, & Schwarte, 2018). Table 10 indicates there are strong positive correlations between the identical constructs from

Time 1 to Time 2. For example, Time 1 Utility Value is significantly positively correlated to the Time 2 Utility Value ( $r(136) = 0.514, p < 0.0005$ ).

Table 10: Correlation matrix for expectancy, utility value, and cost measures.

	1	2	3	4	5
1. T1 E Mean					
2. T1 U Mean	0.467 ***				
3. T1 C Mean	-0.378 ***	-0.275 ***			
4. T2 E Mean	0.439 ***	0.248 **	-0.293 ***		
5. T2 U Mean	0.258 **	0.514 ***	-0.226 **	0.498 ***	
6. T2 C Mean	-0.090	-0.172 *	0.447 ***	-0.371 ***	-0.284 **

Note:  $N = 138$ . Note: \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ .

### Factor Analysis

Factor analysis of the 25-item instrument was used to confirm the presence of the four factors. Previous studies (C. Hulleman et al., 2010; C. S. Hulleman et al., 2017) verified a four factor model including expectancy, utility value, cost and interest. Analysis from a pilot study performed in Fall 2019 indicated the presence of five factors, including an additional interest factor. When looking at the nature of the questions in the interest category, it was determined that the instrument was indeed looking at interest from two perspectives: interest in the design process, and interest in the class. The measured factor structure of the instrument was changed based on the pilot. Factor loadings for the pilot study is included in Appendix E. Factor analysis was again performed on the Time 1 data shown in Table 11. Primary factor loadings of 0.40 and above are within the acceptable cut-off criterion (Hair et al., 1998; Kline, 2014). All items meet the acceptable threshold, allowing all items to remain in the instrument. Equimax rotation was used to create the clearest factor loading structure by combining techniques used in Varimax rotation and Quartermax rotation methods (Minitab, 2020).

Table 11: Factor loadings and communalities based on Maximum Likelihood factor analysis with Equimax rotation for 25 items. ( $N = 138$ )

Variable	Factors				
	Interest in Design	Utility Value	Interest in the class	Expect- ancy	Cost
I know I can learn the material for this class.				0.75	
I expect to do well in this class.				0.78	
I am confident that I will be successful in this class.				0.87	
I am confident I learned the material in this class.				0.85	
I can apply what we learned in this class to the real world.		0.53			
The course material is relevant to my future career plans.		0.82			
The material is personally relevant to me.		0.67			
I see how what we are studying is important to my future career.		0.74			
The material in this class is useful in my everyday life.		0.52			
Learning the course material will help me achieve my future goals.		0.64			
This semester, I don't have the time to put into this class.					-0.80
Doing well in this class isn't worth all the things that I have to give up.					-0.78
I am unable to invest the effort that is needed to do well in this class.					-0.76
This class requires too much time.					-0.63
Unfortunately, I can't put as much time into this class as I would like.					-0.60
I think the engineering design process is very interesting.	0.85				
I find the engineering design process fascinating	0.88				
I think the engineering design process is an important subject.	0.69				
I am excited about this class			0.74		
I would recommend this class to others.			0.78		
I really enjoy this class.			0.91		
My experience in the course has made me want to take more engineering design courses.			0.55		
To be honest, I just don't find the engineering design process interesting.	0.55				
I think the material in this class is boring.			0.43		
Engineering design fascinates me.	0.69				

The same analysis was performed on the Time 2 data set with similar results, factor loadings are provided in Appendix F. The five factors explain 72.7% of the variance. A scree plot, shown in Figure 5, confirms the five factors by ordering the eigenvalues from largest to smallest. Five of the factors have an eigenvalue greater than one (range 10.8 to 1.11) which is aligned with the Kaiser-Guttman Rule (Kaiser, 1991). Figure 5 show the scree plot levels-off after the fifth factor.

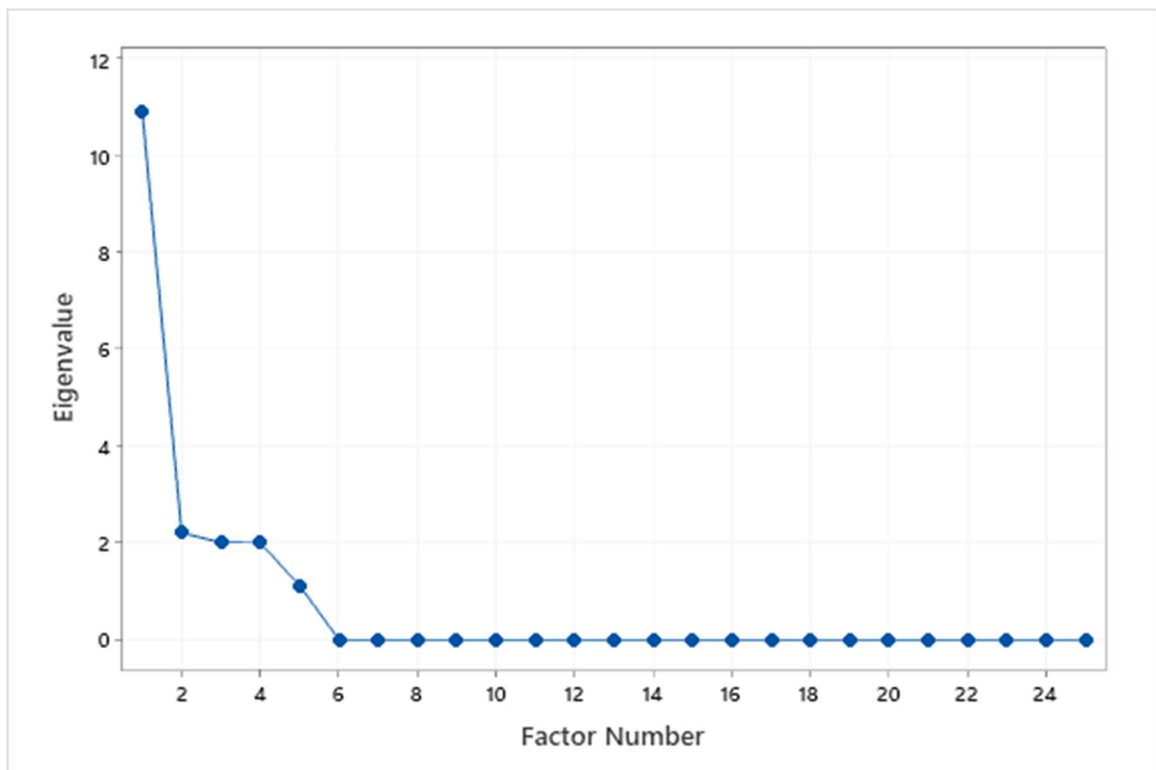


Figure 5: Factor analysis scree plot Time 2.

### Research Questions - Effects on Study Sample

The first set of research questions investigates the general study sample to determine the effect of the utility value interventions on interest and performance in the

course. The analysis is divided into two parts. The first section focuses on interest measures and the second part focuses on performance measures. Two-sample *t-tests* and paired *t-test* are used to understand differences between and within the control and treatment groups. The analysis for this first set of research questions concludes with a linear regression model looking at the influence of the motivation variables (expectancy, utility value, and cost) and the outcome variables (interest and performance).

Research Question 1(a) Does a utility value intervention affect student interest in a multidisciplinary engineering design course? The first step to answering the question was to understand the level of interest for both groups (control and treatment) at the beginning of the semester, Time 1. An independent *t-test* was run on the data with a 95% confidence interval for the mean difference. There was no significant difference ( $p = 0.540$ ) in the interest in the design process for the control and treatment groups, but interest in the class was significantly higher for the treatment group ( $p = 0.007$ ) as shown in Figure 6.

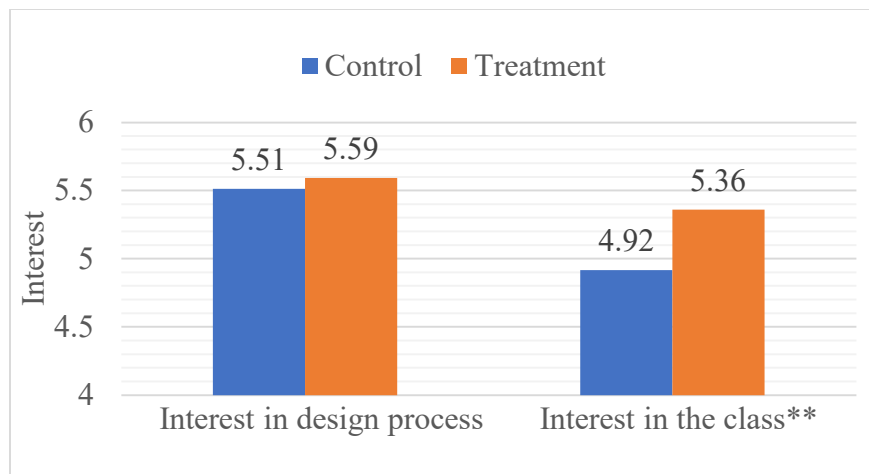


Figure 6: Difference in interest between control and treatment groups at Time 1. Note: \*  $p < 0.05$ , \*\*  $p < 0.01$ .

The same procedure was used to test the difference between the groups at Time 2. It was found at the end of the semester, after the interventions, there was significantly higher interest in the design process ( $p = 0.008$ ). Interest in the class was also significantly higher at Time 2 ( $p = 0.016$ ) for the treatment group but this results shows consistency from Time 1 to Time 2 as shown in Figure 7.

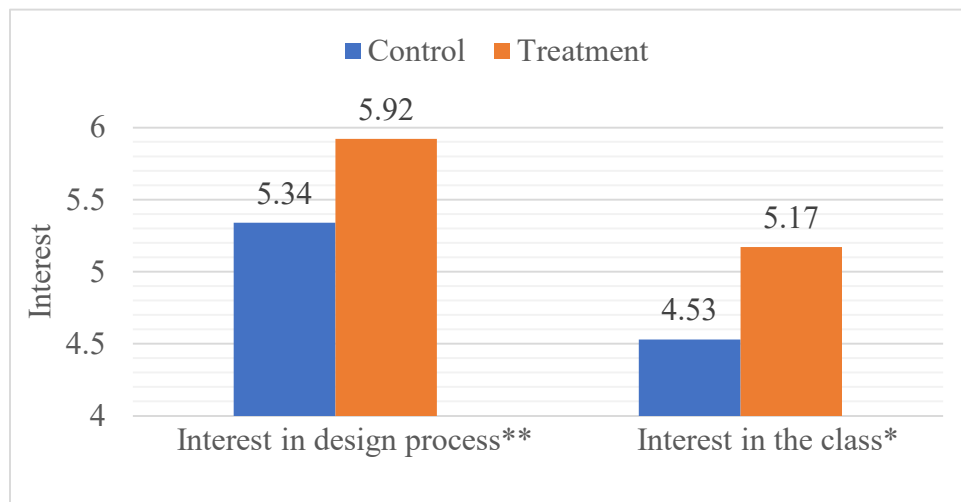


Figure 7: Difference in interest between control and treatment groups at Time 2. Note: \*  $p < 0.05$ , \*\*  $p < 0.01$ .

The above analysis highlights the difference between the groups over time. It is also important to understand the difference within the groups over time. A dependent  $t$ -test, or paired  $t$ -test, was used to determine whether the mean of the dependent variable is the same within the two groups (control and treatment). This was examined at the beginning of the course and at the end of the course. As shown in Figure 8, the results show no statistical difference in the control group for the change in interest of the design process from Time 1 to Time 2 ( $p = 0.163$ ). The results show a significant increase in interest in the design process for the treatment group ( $p = 0.013$ ).

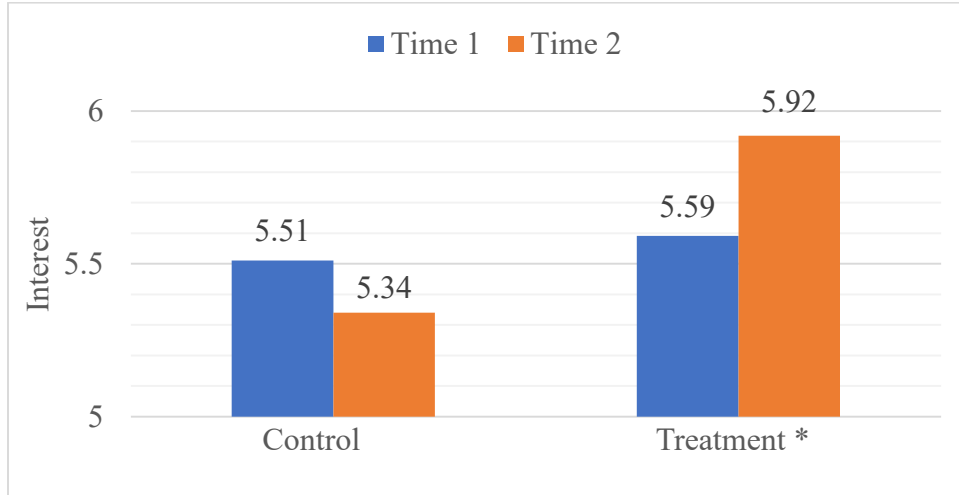


Figure 8: Change in interest of the design process over time for control and treatment groups. Note: \*  $p < 0.05$ , \*\*  $p < 0.01$ .

The same procedure was used to test the difference within the groups for interest in the class over time. Results show a significant *decrease* in interest of the class for the control group over the semester ( $p = 0.018$ ) and no significant difference in interest of the class for the treatment group ( $p = 0.345$ ).

Linear regression was used to understand the relationship between the independent motivation variables and the dependent interest variables. The first regression model used the change in motivation measures to predict the change in interest measures. From the results shown in Table 12, utility value is a significant positive predictor on interest in the design process and interest in the class. Participation in the treatment group is a significant predictor for the change in interest of the design process but not for interest in the class. These are similar to the findings from the *t*-tests. Expectancy is a significant positive predictor for interest in the class, while cost is a significant negative predictor for interest in the class. The results are consistent with the

findings from the *t*-tests. The dependent variables in the model for interest in design explains 18.75% of the variance ( $R^2 = 18.75\%$ ). This model meets what is commonly reported for these types of human behavior studies including the study this research was modeled after (C. Hulleman et al., 2010). For this particular model the score is lower meaning there is high variability in the terms, however utility value and control are still significant predictors in the model. The other regression models in the current study have higher  $R^2$  values.

Table 12: Regression model coefficients predicting change in interest given change in motivation measures.

	<b>Change in Interest in Design</b>	<b>Change in Interest in the class</b>
	$\beta$ Coef.	$\beta$ Coef.
Change Expectancy	0.106	0.339**
Change Utility Value	0.268***	0.611***
Change Cost	-0.017	-0.153*
Control	0.476**	0.208
$R^2$	18.75%	47.61%

Note:  $N = 138$ . Note: \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ .

From these results, it is important to understand the benchmark or initial interest levels at the beginning of the semester to recognize if any of the initial motivation measures were predictors for initial interest. This second model used the Time 1 self-reported data. From the results shown in Table 13, utility value is a significant positive predictor on interest in the design process and interest in the class. Participation in the treatment group is a significant predictor for interest in the class but not for interest in the design process. Expectancy is a positive significant predictor for interest in the design process, while cost is not a significant predictor for either.

Table 13: Regression model predicting initial interest measures given initial motivation measures.

	Time 1	Time 1
	Interest in Design	Interest in the class
	$\beta$ Coef.	$\beta$ Coef.
Time 1 Expectancy	0.176**	0.071
Time 1 Utility Value	0.318***	0.511***
Time 1 Cost	0.047	-0.057
Control	-0.043	0.280*
R <sup>2</sup>	34.17%	47.54%

Note:  $N = 138$ . Note: \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ .

Additional analysis of the main regression models examined the pairwise Pearson's product-moment correlation on the independent variables. The model showed strong positive correlations between utility value and expectancy ( $r(138) = 0.442, p < 0.0005$ ). Table 14, also indicated a strong negative correlation between expectancy and cost ( $r(138) = -0.332, p < 0.0005$ ). There was no significant relationship between utility value and cost. These results are consistent with expectancy-value theory in that cost had a negative relationship with expectancy. Cost is also a component of the task value just like utility value, they both relate to task value and are shown to not be significantly correlated to each other in this model.

Table 14: Pairwise Pearson Correlations

Sample 1	Sample 2	Correlations	98% CI for p	P-Value
Change Utility	Change Expectancy	0.442	(0.30, 0.57)	0.000***
Change Cost	Change Expectancy	-0.332	(-0.74, -0.17)	0.000***
Change Cost	Change Utility	-0.156	(-0.31, 0.01)	0.068

Note:  $N = 138$ . Note: \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ .

Multicollinearity was assessed using variance inflation factor (VIF), which measures how much the variance of an estimated regression coefficient increases if the independent variables are correlated. VIF values between 1 and 5 indicate a moderate correlation while values greater than 5 or 10 suggest severe multicollinearity (Neter, Kutner, Nachtsheim, & Wasserman, 1996). Tables 15 and 16 specify the regression coefficients and VIF values for both models. The VIF values in the models range from 1.01 to 1.37 indicating moderate multicollinearity, which was not considered a source of concern for this study.

Table 15: Coefficients for change in interest of the design process.

<b>Term</b>	<b>Coef.</b>	<b>SE Coef.</b>	<b>T-Value</b>	<b>P-Value</b>	<b>VIF</b>
Constant	-0.073	0.118	-0.62	0.537	
Change Expectancy	0.106	0.095	1.12	0.266	1.37
Change Utility	0.268	0.077	3.47	0.001***	1.25
Change Cost	-0.017	0.062	-0.28	0.783	1.12
Control	0.476	0.167	2.86	0.005**	1.01

Note:  $N = 138$ . Note: \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ .

Table 16: Coefficients for change in interest in the class.

<b>Term</b>	<b>Coef.</b>	<b>SE Coef.</b>	<b>T-Value</b>	<b>P-Value</b>	<b>VIF</b>
Constant	-0.153	0.132	-1.16	0.250	
Change Expectancy	0.339	0.106	3.19	0.002**	1.37
Change Utility	0.611	0.087	7.05	0.000***	1.25
Change Cost	-0.153	0.070	-2.18	0.031*	1.12
Control	0.208	0.187	1.12	0.266	1.01

Note:  $N = 138$ . Note: \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.0001$ .

Research Question 1(b) Does a utility value intervention affect student performance in a multidisciplinary engineering design course? To answer this question, two individual assignments were graded and combined to provide a single performance

metric. Initial descriptive statistics show large skewness and kurtosis values for the performance distribution in both the control (skewness = -3.99, kurtosis = 17.31) and treatment groups (skewness = -2.60, kurtosis = 6.71). A histogram of the data in Figure 9 also revealed a skewness to the right.

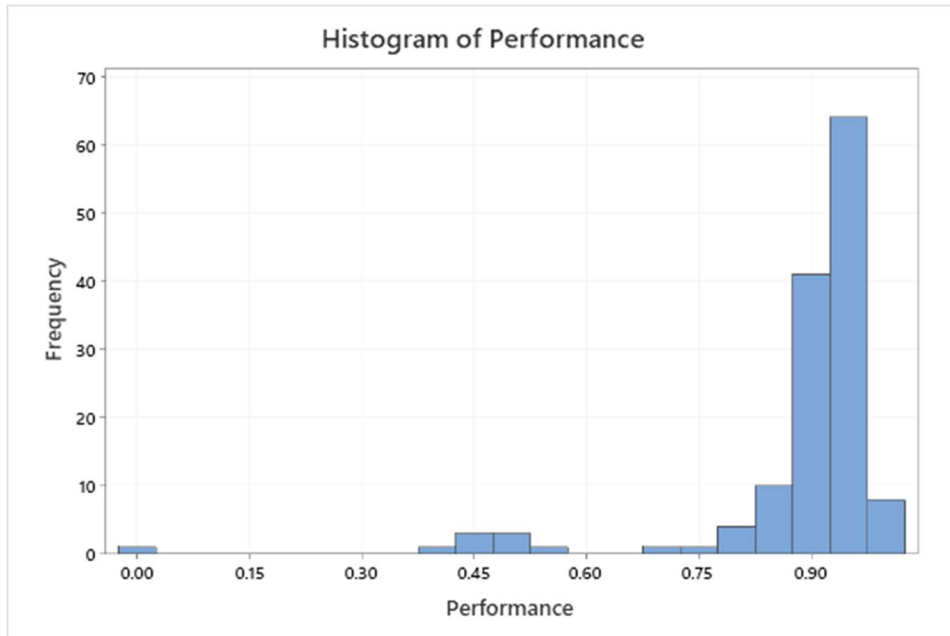


Figure 9: Histogram of performance.

The histogram indicates a multimodal distribution with a skewness to the left indicating higher grades (Alreck, 2004). This was mostly attributed to students submitting none, one, or all the assignments. Variance in students' abilities represented through bimodal grade distribution can represent two different groups: one with low grades and one with very high grades. Researchers have addressed this issue and suggested possible causes for the variance in students' abilities (Wankat, 1999). They suggest the main cause of this bimodal grade distribution is a lack of proper learning habits (Yadin, 2013). A habit of academic procrastination has been shown to be

predicted by low self-efficacy and lower expectancies for success (Klassen, Krawchuk, & Rajani, 2008).

The group considered to have high grades, within the largest multimodal distribution, contained the majority ( $n = 129$ , 93%) of the of the study sample. Due to the small sample sizes of the other groups, only the students who completed both assignments were used for this research question. A normality test was then performed again for the treatment (skewness = -3.30, kurtosis = 11.01) and control groups (skewness = -2.60, kurtosis 6.71). West, Finch, and Curran (1995) suggest skewness above 2 and kurtosis above 7 do not meet normality guidelines. With normality assumptions not being met, the Kruskal-Wallis test for non-parametric data was used to compare the medians of two groups (Kruskal & Wallis, 1952). For students completing both performance assignments, the control group had a significantly higher median performance score (control median = 0.96, treatment median = 0.91,  $p = 0.000$ ).

Further analysis of the treatment group looked at the difference between the two classes, Class A and Class D. Class A students began the class with the lowest average GPA for any of the four classes. The Kruskal-Wallis test showed no significant difference in the medians of Class A (median = 0.90) and Class D (median = 0.92).

#### Research Question - Effect on Low-Performing Students

The second set of research questions seeks to understand if there are differences in interest and performance for low-performing students receiving the intervention. The analysis for these research questions is very similar to the previous research questions with the first section focusing on interest measures and the second part focusing on

performance measures. The focus of the analysis centers around the group receiving the interventions. The control group is compared later. Two-sample *t*-tests and paired *t*-tests are used to understand differences within and between the groups (low-performing and other students receiving the utility value intervention). The analysis concludes with a linear regression model looking at the influence of the motivation variables (expectancy, utility value, and cost) and the outcome variables (interest and performance).

As mentioned previously, low-performing students were identified as having a GPA one standard deviation below the mean for their specific major. There were 27 low-performing students in the treatment group. Table 17 summarizes the GPA statistics for each discipline including the mean and standard deviation.

**Table 17: List of Disciplines with GPA mean and standard deviation.**

<b>Discipline</b>	<b><i>N</i></b>	<b>Mean</b>	<b>Std. Dev.</b>
CET/MET	8	3.153	0.480
Chemical Eng.	26	3.553	0.348
Civil Eng.	22	3.186	0.504
Computer Eng.	7	3.426	0.563
Computer Science	8	3.289	0.462
Electrical Eng.	13	3.323	0.406
Industrial Eng.	6	3.208	0.345
Mechanical Eng.	48	3.384	0.411

Research Question 2(a) Do utility value interventions impact low-performing students' interest differently than other students? The first step to answering the question was to understand the level of interest for both groups (low-performing and other) at the beginning of the semester, Time 1. A two sample *t*-test was run on the data with a 95% confidence interval for the mean difference. At the beginning of the semester, prior to

the interventions, there was no significant difference ( $p = 0.789$ ) in the interest in the design process or interest in the class ( $p = 0.587$ ) for either group. See Figure 10.

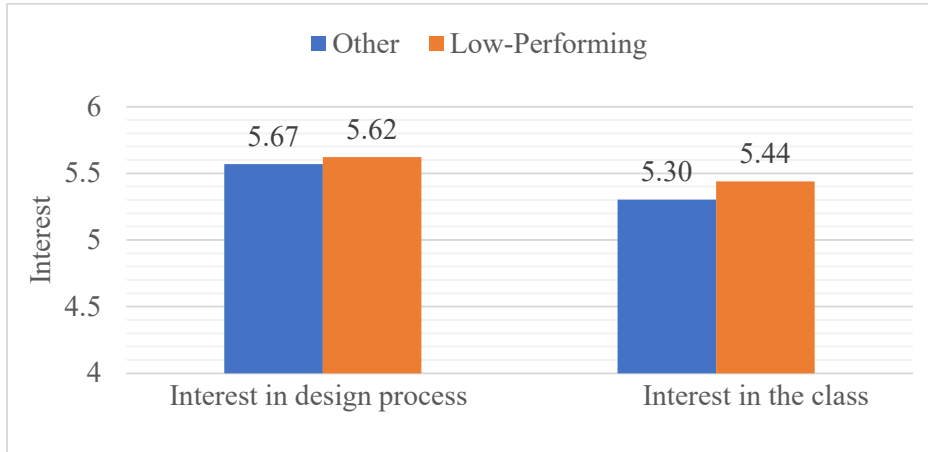


Figure 10: Difference in interest between other and low-performing groups at Time 1 for the treatment group. Note: \*  $p < 0.05$ , \*\*  $p < 0.01$ .

The same procedure was used to test the difference between the groups at Time 2. At the end of the semester, after the interventions, there was no significant difference on the interest in the design process ( $p = 0.807$ ) or in the class ( $p = 0.342$ ) for the either group. See Figure 11.

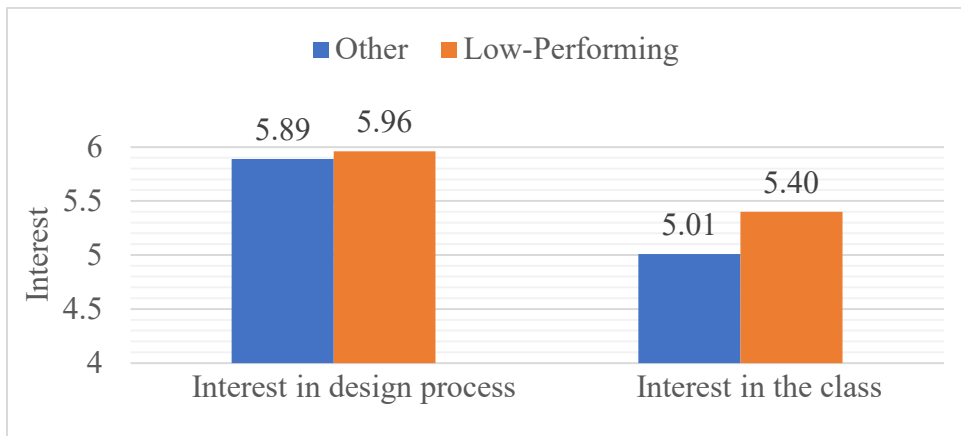


Figure 11: Difference in interest between other and low-performing groups at Time 2. Note: \*  $p < 0.05$ , \*\*  $p < 0.01$ . The above analysis highlights the difference between the

groups over time. It is also important to understand the difference within the groups over time. A dependent *t*-test, or paired *t*-test, was used to determine whether the mean of the dependent variable is the same in two related groups (other and low-performing). This was examined at the beginning of the course and at the end of the course. The results show no statistical difference in the other group for the change in interest of the design process from Time 1 to Time 2 ( $p = 0.085$ ) or for the low-performing students ( $p = 0.071$ ). See Figure 12.

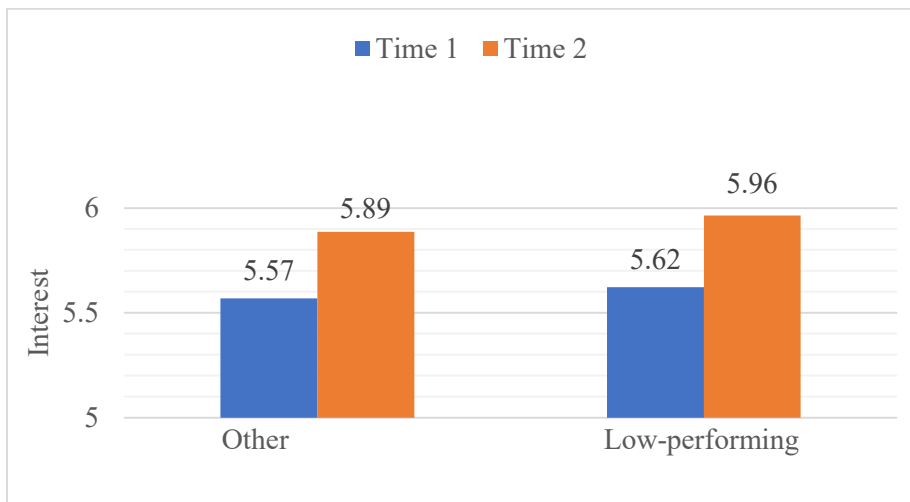


Figure 12: Change in interest of the design process over time for other and low-performing groups. Note: \*  $p < 0.05$ , \*\*  $p < 0.01$ .

The same procedure was used to test the difference within the groups for interest in the class over time. The results show no statistical difference in the other performing student change in interest of the design process from Time 1 to Time 2 ( $p = 0.223$ ) or for the low-performing students ( $p = 0.906$ ). See Figure 13.

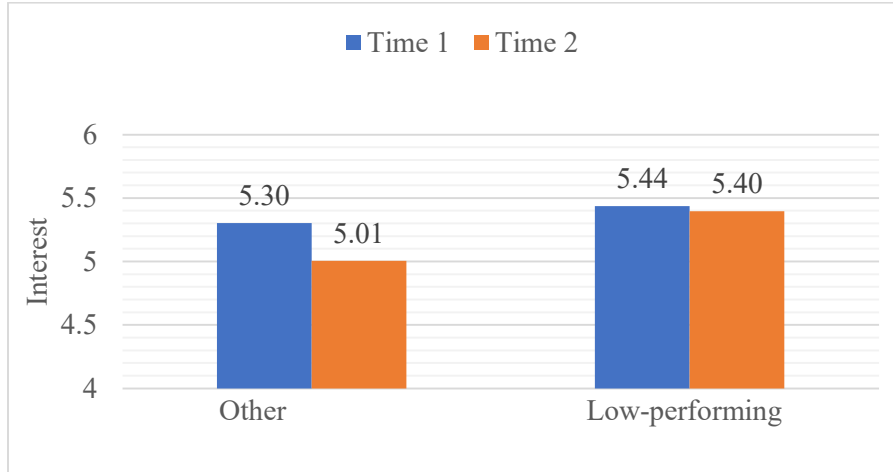


Figure 13: Change in interest of the class over time for other and low-performing groups. Note: \*  $p < 0.05$ , \*\*  $p < 0.01$ .

Identical analysis was performed for the control group. Both measures of difference within and between groups were conducted. Table 18 summarizes the results for both the control and treatment group regarding the change in interest in the design process and in the class over time. There were no significant differences within the groups for the treatment group. The control group indicated a significant decline in interest in the class from Time 1 to Time 2.

Table 18: Change in Interest over time for control and treatment groups according to other and low-performing students.

	Other			Low-Performing		
	Mean T1	Mean T2	<i>p</i> -value	Mean T1	Mean T2	<i>p</i> -value
<b>Control</b>						
Interest in Design	5.51	5.22	0.063	5.51	5.57	0.766
Interest in Class	4.81	4.36	0.016*	5.11	4.85	0.403
<b>Treatment</b>						
Interest in Design	5.57	5.89	0.085	5.62	5.96	0.071
Interest in Class	5.30	5.01	0.223	5.44	5.40	0.906

Note: \*  $p < 0.05$ , \*\*  $p < 0.01$ .

The difference between groups used a two-sample *t*-test to understand the interest measures samples at the same time for the low-performing students and other students. Both measures were calculated for control and treatment groups. There were no significant differences in any interest measures between groups at Time 1 and Time 2. These results are summarized in Table 19.

Table 19: Interest at Time 1 and Time 2 for Control and Treatment groups according to low-performing and other students.

	Control			Treatment		
	Mean Low	Mean Other	<i>p</i> -value	Mean Low	Mean Other	<i>p</i> -value
Time 1						
Interest in Design	5.51	5.50	0.992	5.57	5.62	0.789
Interest in Class	4.82	5.11	0.211	5.30	5.44	0.587
Time 2						
Interest in Design	5.22	5.57	0.283	5.89	5.96	0.807
Interest in Class	4.36	4.85	0.208	5.01	5.40	0.342

Note: \*  $p < 0.05$ , \*\*  $p < 0.01$ .

Linear regression was used to understand the relationship between the independent motivation variables and the dependent interest variables. The first regression model used the change in motivation measures to predict the change in interest measures. From the results shown in Table 20, utility value is a significant positive predictor on interest in the design process and interest in the class for all except the low-performing students' interest in the design process. Change in perceived utility value is not a significant predictor for change in interest of the design process for low-performing students.

Table 20: Regression model coefficients predicting change in interest given change in motivation measures for other and low-performing groups.

	Other		Low-performing	
	Change in Interest in Design	Change in Interest in the class	Change in Interest in Design	Change in Interest in the class
Change Expectancy	0.079	0.251	0.080	0.166
Change Utility Value	0.574**	1.193***	0.296	0.681**
Change Cost	0.082	-0.342	-0.051	-0.094
R <sup>2</sup>	47.37%	57.25%	14.89%	41.89%

Note: \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ .

Research Question 2(b) Do utility value interventions impact low-performing students' performance differently than other students? The analysis for this question is similar to analysis for questions 1(b). The distribution for the performance measure did not meet tests for normality. The Kruskal-Wallis test for non-parametric data was used to compare the medians of two groups (low-performing and other) (Kruskal & Wallis, 1952). For students completing both performance assignments and the utility value interventions, the other group had a significantly higher median performance score (other median = 0.93, low-performing median = 0.89,  $p = 0.001$ ).

Understanding the difference in the medians of the two groups is important but it is also helpful to look at the relationship between the predictor variables and the outcome variables. Regression analysis would typically be considered but due to the non-parametric nature of the performance distribution, pairwise comparisons using the Kruskal-Wallis test were used for each motivation measure. Comparison between the two expectancy medians shows no significant differences (other median = 7, low-performing median = 7,  $p = 0.47$ ). There was no significant difference in utility value (other median = 6.00, low-performing median = 6.17,  $p = 0.292$ ) or cost (other median =

4.0, low-performing median = 3.8,  $p = 0.134$ ) between the low-performing and other students.

#### Research Question - Frequency of Connections

The last set of research questions explores how often students are making connections between the course material and their future careers. The three-item frequency measure was self-reported only at Time 2 on a six-point Likert-type scale. Independent  $t$ -tests were analyzed to compare the frequency of connection means between different groups. The connection frequency measure was normally distributed (skewness = 0.17, kurtosis = -0.63), with the mean score of 3.35 out of a possible 6.

Research Question 3(a) Do utility value interventions increase the frequency at which students connect course material to their future careers? Two-sample  $t$ -tests indicate there is no significant difference ( $p = 0.214$ ) between the frequency means for the control ( $M = 3.25$ ) and treatment groups ( $M = 3.46$ ). Further thorough individual analysis of each of the frequency questions indicate no significant differences (frequency question 1,  $p = 0.176$ ; frequency question 2,  $p = 0.397$ ; frequency question 3,  $p = 0.287$ ).

Research Question 3(b) Do utility value interventions increase the frequency for students closer to graduation to connect course material to their future careers? Students within one year of graduation, Spring 2021, were separated from students graduating after Spring 2021. Two-sample  $t$ -tests revealed no significant difference ( $p = 0.885$ ) in the means for students graduating within one year ( $n = 102$ ,  $M = 3.43$ ) and those graduating after one year ( $n = 35$ ,  $M = 3.37$ ) within the total group. Again, individual

analysis of each of the frequency questions indicate no significant differences (frequency question 1,  $p = 0.812$ ; frequency question 2,  $p = 0.862$ ; frequency question 3,  $p = 0.755$ ).

Further One-way ANOVA analysis looked specifically at the difference within the control and treatment groups. The control group showed no significant difference in the means depending on graduation date ( $p = 0.840$ ). The same result holds true for the treatment group ( $p = 0.796$ ). See Figure 14.

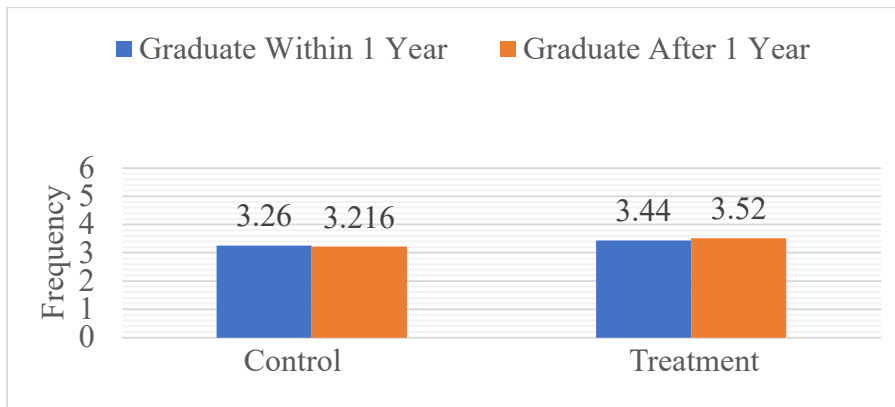


Figure 14: Connection frequency for students depending on graduation date.  
Note: \*  $p < 0.05$ , \*\*  $p < 0.01$ .

## CHAPTER FIVE

## RESULTS, CONCLUSIONS, AND FUTURE WORK

The findings from the current study leveraged previous research on student motivation to understand the effects of utility value interventions on student interest and performance and extend it to a new setting and discipline. That extension looked at specific research questions along three themes: effects on the study sample, effects on low-performing students, and the frequency students are making connections. Results from each of these study areas are investigated in the following sections along with limitations, future work, key findings, and practical applications.

ResultsResearch Questions - Effects on Study Sample

The first set of research questions looks specifically at the effect of the utility value interventions on student interest and performance for the study sample. Interest outcomes are evaluated first, followed by performance outcomes, and finally with discussion of the regression analysis.

Interest Outcomes Does a utility value intervention affect student interest in a multidisciplinary engineering design course? The results showed a significantly higher interest in the design process and interest in the class for the treatment group at the end of the semester, Time 2. The treatment group also showed a significant increase in the interest in the design process over the course of the semester where the control group did

not see a significant change. These findings are consistent with previous research (Harackiewicz & Hulleman, 2010; C. Hulleman et al., 2010; C. S. Hulleman et al., 2008; C. S. Hulleman et al., 2017) and confirm the effectiveness of the utility value interventions in this new setting. Asking students to reflect on the relevance of the course material to their future careers may promote increased engagement and increase intrinsic motivation (Harackiewicz & Sansone, 1991). These empirical measures of students finding value and meaning being able to make applicable connections to their futures are further supported by qualitative results from student writing. The following are direct quotes from student reflections from the first phase of the design process (Discover):

The first thing that comes to mind about relating the discover process to my future career is the problem-solving process. The discover report is a good practice for asking the right/relevant/applicable questions to guide our direction. Learning how to solve problems in a systematic way is very applicable to both career and life.

The discover phase has given me an idea of how my future career will operate....I find these topics very interesting and a career in this field of work would be really exciting for me.

Student responses indicate associations are being made not only with the course material but also in experience with design process. One student explicitly references interest and excitement for a future career. While these quotes provide a deeper view of the impact students experienced, some concern about the reliability of the responses is warranted. The responses included student names and were collected by the instructors. While only participation grades of pass/fail were given, there could be a subconscious motivation for students to write what they think the instructor wants to hear and not what they actually think or feel. However, in evaluating other responses, not all were as

positive and made the connections so clearly. Therefore, this social desirability bias (Nederhof, 1985), if present, does not appear widespread.

There is an additional finding from the interest in the class from Time 1 to Time 2 for the treatment group. Interest in the class was significantly higher at both Time 1 and Time 2. However, interest in the class for the control group significantly decreased in the same time frame. This indicates the interventions did not harm interest for the treatment groups, but the absence of participation did damage the control group.

Performance Outcomes Does a utility value intervention affect student performance in a multidisciplinary engineering design course? Initial analysis to answer this question centered on the distribution of the performance metric. As previously mentioned, Kruskal-Wallis test were used to evaluate the measures since the performance distribution did not meet normality criteria. Unexpectedly, the control group had a significantly higher median performance score than the treatment group on the graded assignments. This outcome is not consistent with other utility value interventions (C. S. Hulleman et al., 2017). In the research design, one of the anticipated outcomes for the utility value interventions was not only for an increase in the interest of the course but also an increase in the performance of the course and this test refuted that expectation. The significant increase for the control group could be explained by the incoming student GPA. As previously mentioned, Class A and Class D both had the lowest average GPA for the four classes studied, refer to Table 5. They are also the two classes used for the treatment condition. Further analysis reveals a significant difference in the average GPA for the control and treatment groups ( $p = 0.037$ ).

A secondary explanation revolves around the environment and timing of the performance assignments. The two graded assignments were written after the online transition of the class due to the COVID-19 pandemic. During this time, instructors were encouraged to be understanding of the additional stress and demands on students during the pandemic. Instructors were also experiencing stress and unknown circumstances which may have led to more lenient grading practices. These impacts of the uncontrolled variables were not well understood at the time.

Regression Analysis The regression model used the change in motivation, change between Time 1 and Time 2, measures to predict change in the interest measures. Before those results are discussed, it is important to understand at Time 1, utility value was a strong significant predictor for interest in both measures at Time 1. From the initial regression model, participation in the treatment group was a significant predictor for interest in the class at Time 1.

The same pattern of utility value being a strong predictor of both interest measures held true in the second model. This indicates a sustained importance of perceived utility value to interest over the course of the semester. Change in the interest of the class also accounted for expectancy-value being a significant predictor. The expectancy questions, (e.g. “I am confident I will be successful in this class,” “I know I can learn the material for this class.”), may have been difficult for students to answer during week 2 but by week 14, students would have a good understanding of their grade and their material knowledge. It is reasonable to expect this result given the timing of the pre-test and post-test. It is also reasonable that expectancy was not a significant predictor

for interest in the design process. Closer examination of the expectancy items reveals they refer to the class and the material and not the design process. This would explain expectancy only being a significant predictor for interest in the class.

Change in the cost measure was a negative significant predictor for change in interest of the class. The cost items refer to the effort, time, and tradeoffs related to doing well in the class. The negative predictor could indicate students agree there are too many negative consequences or barriers to engaging in the class. Cost was a non-significant predictor for interest in the design process. This could indicate that students were willing to put the time in because they were interested in the design process. This finding is consistent with prior research which demonstrated cost has a negative correlation to task values (Flake et al., 2015).

#### Research Question - Effect on Low-Performing Students

Interest Outcomes The next set of questions examined how utility value interventions impacted low-performing student interest and performance. Do utility value interventions impact low-performing students' interest differently than other students? Analysis indicated no significant change in interest in the design process or interest in the class for low-performing students participating in the utility value interventions. They maintained the same level of interest as other performing students.

This outcome is not consistent with other work in utility value interventions. Previous studies show an increase in both interest and performance when participating in the interventions (C. S. Hulleman et al., 2017). One possible explanation is that the methodology for determining the low-performing students does not translate from study

to study. The low-performing students for Hulleman's study were determined by the performance on the first exam. The current study used incoming longitudinal student data to differentiate the groups, which was felt to be a better indicator of low-performance at the student level. Therefore, the results here may call into question the results using the previously published method.

All interest measures were additionally calculated for the control group. There were no significant differences for low-performing students in the control or treatment groups for either interest measure. One important finding is the interest in the class significantly decreased for the other students in the control group and did not change significantly for the treatment group. This absence of change for the treatment group is encouraging, suggesting interest in the class was maintained through participation in the utility value interventions.

Performance Outcomes The second part of the research question evaluates the performance outcome for low-performing students. Do utility value interventions impact low-performing students' performance differently than other students? Based on literature, it was hypothesized that the intervention could help low-performing students by getting them to achieve at least the same level as other performing students, if not better. However, results showed the low-performing students median score was significantly lower than other performing students as hypothesized. Therefore, the intervention, in this context, did not improve performance for low-performing students. Furthermore, the pairwise comparisons of each motivation measure to the performance measure revealed no significance of expectancy, utility value, or cost to performance.

Again, the method for determining low-performing students could be a factor. An additional factor could be the nature of the performance assignments. As demonstrated in the violation of normality tests, most students scored very high on the performance metrics making it difficult to have a normal distribution, meaning, there is not much variance in the data. Additionally, it is important to note the impact of the COVID-19 pandemic on both student performance and adjustments to grading practices during the study period. It simply may be that data from this time period does not represent a reliable measure of student performance.

#### Research Question - Frequency of Connections

The last set of research questions aims to understand if students who participated in the utility value interventions are making more frequent connections of the course material to their future careers. Do utility value interventions increase the frequency at which students connect course material to their future careers? It was further examined if students who are within one year of graduation are making those connections more frequently than their peers who have a longer expected time in school. Do utility value interventions increase the frequency for students closer to graduation to connect course material to their future careers? Understanding and experiencing the engineering design process is highly relevant to an engineering career. The engineering curriculum at Montana State University is structured for students to learn and participate in the design process as juniors in this course, and then experience it again as seniors in a capstone course. Is there perceived value in experiencing engineering design at the junior level before graduating?

Analysis of the two groups showed no significant difference for the frequency of connections made between the course materials (lecture, homework, and quizzes) to their future careers. This result is unexpected because the treatment group wrote specifically to the relevance of the course material to their future careers. It should be noted the time between the writing prompts and the time of the self-reported frequency measure was six weeks and this delay may have muted any effect. Furthermore, during the six weeks, the course transitioned from in person class to strictly online classes due to the COVID-19 pandemic. It is plausible that students were not as engaged with academic life and not concerned about their future goals during the onset of the pandemic. Perets et al. (2020) found that in an undergraduate chemistry course in the weeks after the emergency transition to on-line learning, students engaged less with course instructions methods related to synchronous classes accessing content on learning management systems. The authors suggest the drop in engagement occurred at the same time the university announced a Pass/Fail grading policy, similar to changes made at Montana State University during the current study.

### Implications and Key Findings

Theoretical Implications This study offers additional support for understanding motivation and interest in engineering education contexts using expectancy-value framework. This framework provides a means to link how perceived utility value of the course is relevant to one's future or goals. The link is measured in student interest for the design process and class material and related back to the motivation constructs of expectancy, utility value, and cost. The role that utility value plays in positively

increasing interest in the design process was validated by the experimental research using a control and treatment group. These findings are supported in other models of interest development (Hidi & Renninger, 2006), which suggest perceiving value in an activity is one way of developing interest.

Practical Implications This research contributes to the growing body of research related to the effective impact of interventions on enhancing educational outcomes (Lazowski & Hulleman, 2016). From a practical perspective, this study confirms the use of an applied tool educators can use to implement educational interventions. The interventions were simple and inexpensive to implement, took little class time and could have possibly been completed outside of class time. The benefit gained from carrying out the interventions in a classroom could possibly outweigh the costs of time and effort on the part of the instructor and students. Results prove no harm was done for students participating in the writing interventions.

Asking students to reflect on the relevance of a topic to their future careers may encourage task engagement leading them to appreciate the utility value of the topic (C. Hulleman et al., 2010). Feelings of involvement have been associated with interest and performance in classroom and laboratory setting (Harackiewicz, Barron, & Elliot, 1998). It is possible when students make connections through writing interventions, they are engaged and feel involved in learning and improve interest and performance outcomes.

Key Findings Three key findings emerged from the above analysis and discussion and are depicted in Figure 15. First, at the end of the course, the treatment group showed significantly higher interest in both the design process and the class. By

indicating higher interest in both measures at the end of the class, the hope is students will connect the relevance of the course to their future goals.

Second, the interventions significantly increased interest in the design process over time for the treatment group. Students writing directly to prompts connecting the design process to their future careers translate to increased interest in design.

Third, utility value is a positive significant predictor of interest in the design process. By encouraging students to think about the usefulness of the class, it became a positive predictor for their interest in the design process.

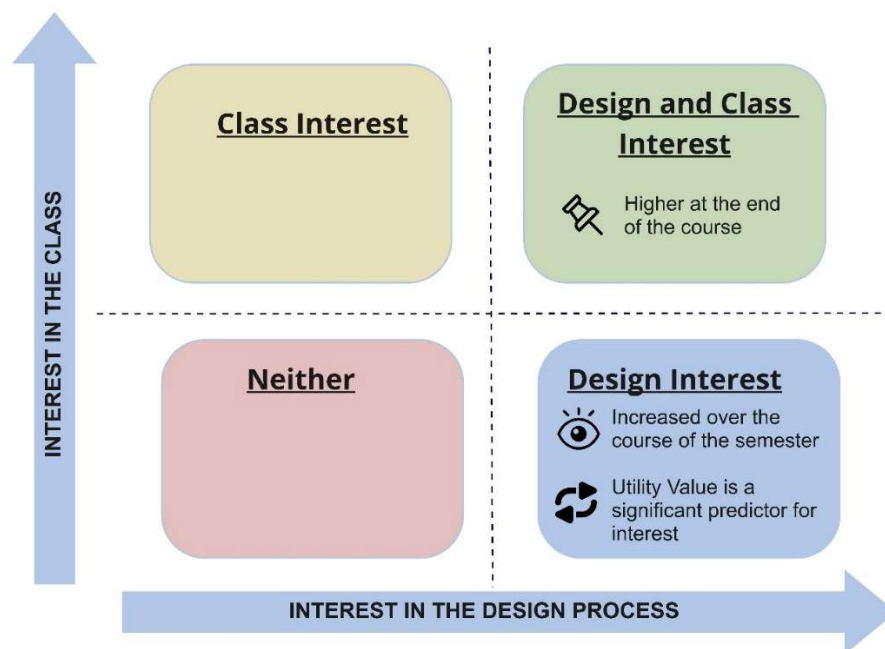


Figure 15: Key findings on interest outcomes for the treatment group.

### Limitations and Future Work

Five key limitations of this study stand out as areas for consideration and for future research. First, the researcher is also an instructor of the course which carries

potential bias and a positionality to the study. The basic motivation for the study comes as the instructor for the course and wanting students to see meaning and value in the course material. Efforts were made to reduce the effect of the instructor as the researcher such as having an additional instructor replicate the study in different classes. Another limitation for the instructor as researcher, students may not answer truthfully to survey questions knowing the instructor is invested in the research. Future work could replicate the study in a different course without the researcher as the instructor.

Second, the timing of the study during a pandemic added limitations. The time frame in which the data was collected was limited to a 15-week semester course that occurred during the onset of the COVID-19 pandemic. The research plan written was based on a traditional instructional model of conducting in-person class where students met three times per week and worked collaboratively with a group on campus. These were assumptions of the study that were not predicted to change during the semester when data collection occurred. The change in modality of delivery and limitation of available resources likely had impacts on learning, engagement, motivation, interest, and many other factors. At the time of the study, these external factors were uncontrolled and uncontrollable. It should also be noted at the time the assignments were performed and graded; the university had transitioned to online instruction and an optional Pass/Fail grading selection. Not only were the students experiencing an unknown environment, the instructors also transitioned to an unfamiliar teaching modality. Instructors were encouraged to consider the unique conditions of the semester and pressures students experienced when finalizing course grades. While these are limitations, future work

could use this data set to investigate motivation and interest in a course when the basic assumptions of in-person class is quickly changed. The study could be replicated in a blended modality to determine if the intervention is generalizable across multiple instructional platforms. Future work could also explore varying the number of utility value interventions given to a class. The current study design included three writing interventions, would it be just as effective with fewer or could the performance outcome increase with more interventions?

Third, the outcome variable of performance is a limitation. While grades as an outcome variable have been used in research with a similar study design (C. Hulleman et al., 2010; C. S. Hulleman et al., 2017), their methods differed from those in this study. Previous work utilized exam and quiz scores to understand the effect of utility value interventions. This study used an essay and reflective assignment to score performance. Grading of these two assignments was more subjective in nature. While a rubric was implemented to increase consistency among graders, this method of measure is inherently more subjective than items such as multiple-choice exams.

Fourth, the connection frequency measure was not found to be significant from those who wrote to the utility value prompt and those who did not. One plausible explanation is the underlying context of COVID-19 and the implications related to online learning, change of routines, and anxiety. The current measure does not describe the quality of connections, merely the frequency. It is also not known if the connections are merely short-term or have longer lasting gains. An extend qualitative study could assess the relevance and quality of the connections and if simply writing encourages the

frequency of connections. Additionally, it is not well understood if the survey questions are adequately reflected for the context of this course. The questions center around making connections with the lectures, outside work, homework and quizzes. The structure of the course relies heavily on interaction with team members and not as much on lecturing and working homework problems. Future work could explore adapting the questions to a group project learning environment.

Finally, as is common in most psychological research, this study used self-report data. One limitation to using self-report data is respondents may answer more favorably to questions, a social desirability bias (Nederhof, 1985). Steps to minimize this were taken by keeping the data anonymous and communicating confidentiality. Surveys were taken in an online platform as an additional step to ensure anonymity. Once responses were combined, data was checked for non-differentiation in answers. Future work could test for socially desirability bias in the question structure of not only the survey questions but in the writing prompts.

### Conclusions

Instructors are in a constant battle to motivate and engage students. Student motivation can be linked to interest in the course. When students see value and relevance, they are more likely to engage and perform better. Prior to this study, course instructors could only make assumptions about student motivation and interest in the multidisciplinary engineering design course. Inferences about student perceptions were based on comments in class, course evaluations, and casual conversations with students. That information made it seem that some students thought the class was valuable while

others thought it was just another box to check to get a degree. Instructors desired a way to help students connect the course material to their future careers so they could see value and relevance in learning the engineering design process. The design of this study allowed assumptions to be challenged and checked against comprehensive student responses. By extending prior research using expectancy-value framework, it allowed for the assessment of a simple tool, utility value writing interventions, to help students make connections of course material to their future careers.

The results from the study were encouraging on many levels and surprising on others. Despite the study being completed during a pandemic, the utility value interventions did significantly increase student interest in the design process and interest in the class at the end of the semester compared to the control group. Over the course duration, participants in the treatment group showed a significant increase in interest in the design process. These results validate the effectiveness of the interventions. However, participation in the interventions did not impact performance outcomes. Prior studies have shown increased academic performance when participating in interventions. It is possible, these performance outcomes could have been influenced by the pandemic.

Grounded in theoretical perspectives, this study demonstrates a practical and effective means to increase interest and student motivation. Utility value interventions are easy and inexpensive to apply, require little preparation or class time, and produce effective results. Educators are encouraged to implement simple relevance interventions to help students make connections of the course material to their future careers. When these connections are made, they can significantly impact motivation and learning.

REFERENCES CITED

- Aiken, L. S., West, S. G., & Reno, R. R. (1991). *Multiple regression: Testing and interpreting interactions*: Sage.
- Alreck, P. L. (2004). *The survey research handbook* (3rd ed., ed.). Boston: Boston : McGraw-Hill/Irwin.
- ASEE. (2017, June 25-28, 2017). Paper presented at the ASEE (American Society for Engineering Education) 2020-2011, Annual Conference and Exposition, Columbus Ohio.
- Atkinson, J. (1958). *Motives in fantasy, action, and society: A method of assessment and study*.
- Atkinson, J. (1964). *An introduction to motivation*. Princeton, NJ: Van Nostrand.
- Bandura, A. (1986). Social foundations of thought and action: a Social Cognitive Theory. In: Prentice-Hall, Englewood Cliffs, NJ.
- Bandura, A. (1997). *Self-Efficacy: The Exercise of Control*: Macmillan.
- Benabou, R., & Tirole, J. (2003). Intrinsic and extrinsic motivation. *The review of economic studies*, 70(3), 489-520.
- Benson, L., McGough, C., Kuzbary, D., & Sharp, J. (2017, June 25-28, 2017). *Longitudinal study of changes in student motivation and attitudes in engineering*. Paper presented at the Proceedings of the Annual Meeting of American Society for Engineering Education (ASEE), Columbus, Ohio.
- Borrego, M., Foster, M. J., & Froyd, J. E. (2014). Systematic literature reviews in engineering education and other developing interdisciplinary fields. *Journal of Engineering Education*, 103(1), 45-76.
- Brown, E. R., Smith, J. L., Thoman, D. B., Allen, J. M., & Muragishi, G. (2015). From bench to bedside: A communal utility value intervention to enhance students' biomedical science motivation. *Journal of Educational Psychology*, 107(4), 1116.
- Brown, P. R., & Matusovich, H. M. (2013, June 23-26). *Unlocking student motivation: Development of an engineering motivation survey*. Paper presented at the American Society of Engineering Education Annual Conference, Atlanta, Georgia.
- Brown, P. R., McCord, R. E., Matusovich, H. M., & Kajfez, R. L. (2015). The use of motivation theory in engineering education research: a systematic review of literature. *European Journal of Engineering Education*, 40(2), 186-205.
- Butler, B., & Bodnar, C. (2017, June 24-28). *Establishing the Impact that Gamified Homework Portals Can Have on Students' Academic Motivation*. Paper presented at the ASEE Annual Conference and Exposition, Columbus, Ohio.
- Connell, J. P., & Wellborn, J. G. (1990). Competence, autonomy, and relatedness: A motivational analysis of self-system processes. In M. R. G. L. A. Sroufe (Ed.), *The Minnesota symposium on child psychology* (Vol. 22, pp. 43-77). Hillsdale, NJ.
- Corno, L. (1993). The best-laid plans: Modern conceptions of volition and educational research. *Educational researcher*, 22(2), 14-22.
- Covington, M. V. (1992). *Making the grade: A self-worth perspective on motivation and school reform*: Cambridge University Press.

- Crandall, V. C., Katkovsky, W., & Crandall, V. J. (1965). Children's beliefs in their own control of reinforcements in intellectual-academic achievement situations. *Child development*, 91-109.
- Deci, E. L., & Ryan, R. M. (1985). The general causality orientations scale: Self-determination in personality. *Journal of research in personality*, 19(2), 109-134.
- Deci, E. L., & Ryan, R. M. (2008). Self-determination theory: A macrotheory of human motivation, development, and health. *Canadian psychology/Psychologie canadienne*, 49(3), 182.
- Duncan, T. G., & McKeachie, W. J. (2005). The making of the motivated strategies for learning questionnaire. *Educational psychologist*, 40(2), 117-128.
- Durik, A. M., & Harackiewicz, J. M. (2007). Different strokes for different folks: How individual interest moderates the effects of situational factors on task interest. *Journal of Educational Psychology*, 99(3), 597.
- Eccles, J. S., Adler, T. F., Futterman, R., Goff, S., Kaczala, C., Meece, J., . . . Spence, J. (1983). In *Achievement and achievement motivation: psychological and sociological approaches* (pp. 75-146).
- Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual review of psychology*, 53(1), 109-132.
- Flake, J. K., Barron, K. E., Hulleman, C., McCoach, B. D., & Welsh, M. E. (2015). Measuring cost: The forgotten component of expectancy-value theory. *Contemporary Educational Psychology*, 41, 232-244.
- Ford, M. J., Ritz, H., & Fisher, E. (2020). *Motivation, self-efficacy, and student engagement in intermediate mechanical engineering courses*. Paper presented at the ASEE's Virtual Conference.
- Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (1998). *Multivariate data analysis* (Vol. 5): Prentice hall Upper Saddle River, NJ.
- Harackiewicz, J. M., Barron, K. E., & Elliot, A. J. (1998). Rethinking achievement goals: When are they adaptive for college students and why? *Educational psychologist*, 33(1), 1-21.
- Harackiewicz, J. M., Barron, K. E., Tauer, J. M., Carter, S. M., & Elliot, A. J. (2000). Short-term and long-term consequences of achievement goals: Predicting interest and performance over time. *Journal of Educational Psychology*, 92(2), 316.
- Harackiewicz, J. M., Canning, E. A., Tibbetts, Y., Priniski, S. J., & Hyde, J. S. (2015). Closing achievement gaps with a utility-value intervention: Disentangling race and social class. *Journal of personality and social psychology*, 111(5), 745.
- Harackiewicz, J. M., & Hulleman, C. S. (2010). The importance of interest: The role of achievement goals and task values in promoting the development of interest. *Social and Personality Psychology Compass*, 4(1), 42-52.
- Harackiewicz, J. M., Rozek, C. S., Hulleman, C. S., & Hyde, J. S. (2012). Helping parents to motivate adolescents in mathematics and science: An experimental test of a utility-value intervention. *Psychological science*, 23(8), 899-906.
- Harackiewicz, J. M., & Sansone, C. (1991). Goals and intrinsic motivation: You can get there from here. *Advances in motivation and achievement*, 7, 21-49.

- Hicks, N., & Diefes-Dux, H. (2017). *Grader consistency in using standards-based rubrics*. Paper presented at the Proc. American Society for Engineering Education Conference & Exposition, Columbus, OH.
- Hidi, S. (2001). Interest, reading, and learning: Theoretical and practical considerations. *Educational psychology review*, 13(3), 191-209.
- Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational psychologist*, 41(2), 111-127.
- Hulleman, C., Godes, O., Hendricks, B., & Harackiewicz, J. (2010). Enhancing Interest and Performance With a Utility Value Intervention. *Journal of Educational Psychology*, 102, 880-895. doi:10.1037/a0019506
- Hulleman, C. S., Durik, A. M., Schweigert, S. B., & Harackiewicz, J. M. (2008). Task values, achievement goals, and interest: An integrative analysis. *Journal of Educational Psychology*, 100(2), 398.
- Hulleman, C. S., Kosovich, J. J., Barron, K. E., & Daniel, D. B. (2017). Making connections: Replicating and extending the utility value intervention in the classroom. *Journal of Educational Psychology*, 109(3), 387.
- Jackson, A., Mentzer, N., Kramer, R., & Zhang, J. (2017, June 24-28). *Enhancing student motivation and efficacy through soft robot design*. Paper presented at the 2017 ASEE Annual Conference & Exposition, Columbus, Ohio.
- Jamieson, S. (2004). Likert scales: how to (ab) use them. *Medical education*, 38(12), 1217-1218.
- Jones, B. D., Paretti, M. C., Hein, S. F., & Knott, T. W. (2010). An analysis of motivation constructs with first-year engineering students: Relationships among expectancies, values, achievement, and career plans. *Journal of Engineering Education*, 99(4), 319-336.
- Kaiser, H. F. (1991). Coefficient alpha for a principal component and the Kaiser-Guttman rule. *Psychological reports*, 68(3), 855-858.
- Kirn, A., & Benson, L. (2013, October 23-26). *Quantitative assessment of student motivation to characterize differences between engineering majors*. Paper presented at the 2013 IEEE Frontiers in Education Conference (FIE), Oklahoma City, Oklahoma.
- Kirn, A., Morkos, B., & Benson, L. (2012, October 3-6). *Work in progress: How differences in student motivation characterize differences between engineering disciplines*. Paper presented at the 2012 Frontiers in Education Conference Proceedings, Seattle, Washington.
- Klassen, R. M., Krawchuk, L. L., & Rajani, S. (2008). Academic procrastination of undergraduates: Low self-efficacy to self-regulate predicts higher levels of procrastination. *Contemporary Educational Psychology*, 33(4), 915-931.
- Kline, P. (2014). *An easy guide to factor analysis*: Routledge.
- Kosovich, J. J., Hulleman, C. S., Phelps, J., & Lee, M. (2019). Improving Algebra Success with a Utility-Value Intervention. *Journal of Developmental Education*, 42(2), 2-10.
- Kruskal, W. H., & Wallis, W. A. (1952). Use of ranks in one-criterion variance analysis. *Journal of the American statistical Association*, 47(260), 583-621.

- Kuhl, J. (1987). Action control: The maintenance of motivational states. In *Motivation, intention, and volition* (pp. 279-291): Springer.
- Lazowski, R. A., & Hulleman, C. S. (2016). Motivation interventions in education: A meta-analytic review. *Review of Educational Research, 86*(2), 602-640.
- Mamaril, N., Usher, E., Economy, D., & Kennedy, M. S. (2013). *An examination of students' motivation in engineering service courses*. Paper presented at the 2013 IEEE Frontiers in Education Conference (FIE).
- Minitab. (2020). Enter your data for Factor Analysis.
- Nederhof, A. J. (1985). Methods of coping with social desirability bias: A review. *European journal of social psychology, 15*(3), 263-280.
- Neter, J., Kutner, M. H., Nachtsheim, C. J., & Wasserman, W. (1996). *Applied linear statistical models*. Chicago: Irwin.
- Oakleaf, M. (2009). Using rubrics to assess information literacy: An examination of methodology and interrater reliability. *Journal of the American Society for Information Science and Technology, 60*(5), 969-983.
- Olson, G. (1997). Motivation, motivation, motivation-Secondary school educators. [sysiwyg://934/http://7-12educators. about... 12educators/library/weekly/aa071897. htm](http://934/http://7-12educators.about...12educators/library/weekly/aa071897.htm).
- Panchal, J. H., Adesope, O., & Malak, R. (2012). Designing undergraduate design experiences—A framework based on the expectancy-value theory. *International journal of engineering education, 28*(4), 871.
- Panizo, M. T., Williamson, C. M., Pierrakos, O., Anderson, R. D., Bethke, V., & Welch, C. A. (2015, October 21-24). *Engineering students' motivational beliefs: Development of a scale utilizing an expectancy, value, and cost framework*. Paper presented at the 2015 IEEE Frontiers in Education Conference (FIE), El Paso, TX.
- Perets, E. A., Chabeda, D., Gong, A. Z., Huang, X., Fung, T. S., Ng, K. Y., . . . Yan, E. C. (2020). Impact of the Emergency Transition to Remote Teaching on Student Engagement in a Non-STEM Undergraduate Chemistry Course in the Time of COVID-19. *Journal of Chemical Education, 97*(9), 2439-2447.
- Perez, T., Cromley, J. G., & Kaplan, A. (2014). The role of identity development, values, and costs in college STEM retention. *Journal of Educational Psychology, 106*(1), 315.
- Pintrich, P. R. (1991). *A manual for the use of the Motivated Strategies for Learning Questionnaire (MSLQ)*. Ann Arbor, MI: University of Michigan, National Center for Research to Improve Postsecondary Teaching and Learning.
- Pintrich, P. R. (2002). *Motivation in education : theory, research, and applications* (2nd ed.. ed.). Upper Saddle River, N.J.: Upper Saddle River, N.J. : Merrill.
- Pintrich, P. R., Smith, D. A., Garcia, T., & McKeachie, W. J. (1993). Reliability and predictive validity of the Motivated Strategies for Learning Questionnaire (MSLQ). *Educational and psychological measurement, 53*(3), 801-813.
- Renninger, K. A. (1992). Individual interest and development: Implications for theory and practice. *The role of interest in learning and development, 26*(3-4), 361-395.
- Renninger, K. A., & Hidi, S. (2015). *The power of interest for motivation and engagement*: Routledge.

- Rogers, P., Davis, D., Winfree, S., Ash, K., Ibrahim, B., & Ding, L. (2017, June 24-28). *Early Validation of the Motivation in Team Projects (MTP) Assessment*. Paper presented at the Proceedings American Society for Engineering Education Annual Conference, Columbus, Ohio.
- Schober, P., Boer, C., & Schwarte, L. A. (2018). Correlation coefficients: appropriate use and interpretation. *Anesthesia & Analgesia*, *126*(5), 1763-1768.
- Wankat, P. C. (1999). Reflective analysis of student learning in a sophomore engineering course. *Journal of Engineering Education*, *88*(2), 195-203.
- Weiner, B. (1980). May I borrow your class notes? An attributional analysis of judgments of help giving in an achievement-related context. *Journal of Educational Psychology*, *72*(5), 676.
- Weiner, B. (1985). An attributional theory of achievement motivation and emotion. *Psychological review*, *92*(4), 548.
- West, S. G., Finch, J. F., & Curran, P. J. (1995). Structural equation models with nonnormal variables: Problems and remedies. In *Structural equation modeling: Concepts, issues, and applications*. (pp. 56-75). Thousand Oaks, CA, US: Sage Publications, Inc.
- Wigfield, A., & Eccles, J. S. (2000). Expectancy–value theory of achievement motivation. *Contemporary Educational Psychology*, *25*(1), 68-81.
- Wigfield, A., & Eccles, J. S. (2002). *Development of achievement motivation*. San Diego: San Diego : Academic Press.
- Yadin, A. (2013). Using unique assignments for reducing the bimodal grade distribution. *ACM Inroads*, *4*(1), 38-42.
- Zimmerman, B. J. (2000). Attaining self-regulation: A social cognitive perspective. In *Handbook of self-regulation* (pp. 13-39): Elsevier.
- Zimmerman, B. J., & Martinez-Pons, M. (1992). Perceptions of efficacy and strategy use in the self-regulation of learning. *Student perceptions in the classroom*, 185-207.
- Zimmerman, B. J., & Schunk, D. (2011). Motivational sources and outcomes of self-regulated learning and performance. *Handbook of self-regulation of learning and performance*, *5*(3), 49-64.

APPENDICES

APPENDIX A

UTILITY VALUE WRITING PROMPTS

Intervention Prompt #1 (Discover Phase of Design Process)

Intervention Prompt:

On a sheet of paper, write in 3-4 paragraphs how the material you have been studying in the Discover Phase of the Engineering Design Process relates to your future career. We are not asking you to summarize the material, just to elaborate on its relevance to your future career.

Control Prompt:

On a sheet of paper, summarize the what you know about the Discover Phase of the Engineering Design Process in 3-4 paragraphs. We are not asking you to elaborate on the material, just to summarize the information that you can recall.

Intervention Prompt #2 (Define Phase of Design Process)

Intervention Prompt:

On a sheet of paper, write in 3-4 paragraphs how the material you have been studying in the Define Phase of the Engineering Design Process relates to your future career. We are not asking you to summarize the material, just to elaborate on its relevance to your future career.

Control Prompt:

On a sheet of paper, summarize the what you know about the Define Phase of the Engineering Design Process in 3-4 paragraphs. We are not asking you to elaborate on the material, just to summarize the information that you can recall.

Intervention Prompt #3 (Prototype/Test Phase of Design Process)

Intervention Prompt:

On a sheet of paper, summarize the what you know about the Discover Phase of the Engineering Design Process in 3-4 paragraphs. We are not asking you to elaborate on the material, just to summarize the information that you can recall.

Control Prompt:

On a sheet of paper, summarize the what you know about the Prototype/Test Phase of the Engineering Design Process in 3-4 paragraphs. We are not asking you to elaborate on the material, just to summarize the information that you can recall.

APPENDIX B

INSTITUTIONAL REVIEW BOARD APPROVAL



**INSTITUTIONAL REVIEW BOARD**  
**For the Protection of Human Subjects**  
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**MEMORANDUM**

**TO:** Staci Turoski and William Schell  
**FROM:** Mark Quinn *Mark Quinn*  
Chair, Institutional Review Board for the Protection of Human Subjects  
**DATE:** January 9, 2020  
**RE:** "Advancing Student Motivation and Course Interest through a Utility-Value Intervention in an Engineering Design Context" [ST010920-EX]

The above research, described in your submission of January 8, 2020, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

- (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation; and (iii) the information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by section 16.111(a)(7).
- (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
- (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
- (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
- (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX C

CONSENT FORM AND SELF-REPORT MEASURES

**Expectancy-Value-Cost-Interest Spring 2020 - Week 14**

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Thank you for your interest in this project. You are being asked to participate in a research study on engineering student motivations. This project seeks to understand students' existing interest and value placed on learning the engineering design process. You have been identified as a potential participant due to your enrollment in a junior level multidisciplinary engineering design course.

Participation in all aspects of the project is voluntary. Your decision whether or not to participate will not effect your current or future relations with Montana State University, grade, or class standing. Risks are no more than minimal. There is no direct benefit to you as the participant to you as the participant, but you may experience indirect benefits by contributing to research and/or reflecting on the value of learning. The study is conducted as part of a graduate research project and is not formally funded.

Any information obtained in connection with this research study that can be identified with you will be disclosed only with your permission; your results will be kept confidential. In any written reports or publications, no one will be identified, or identifiable and only group data will be presented. Identifying numbers are collected only to compare scores and grades from before and after participation in different courses within your engineering program. Once collected, all identifying information will be removed from the survey and an identification number will be assigned that is known only to the lead researcher. All physical records will be kept in a locked cabinet and electronic records will be password protected on a secure drive. You are encouraged to ask questions about your participation at any time. Please contact Staci Turoski (406-539-8015, staci.turoski@montana.edu) or William Schell (406-994-5938, wschell@imontana.edu). If you have additional questions about the rights of human subjects involved in research, you can contact the Chair of Montana State University's Institutional Review Board, Mark Quinn (406-994-4707, mquinn@montana.edu).  
AUTHORIZATION: I have read the above and understand the discomforts, inconvenience and risk of this study. By typing my name below, I agree to participate in this research. I understand that I may later refuse to participate, and that I may withdraw from the study at any time.

[Enter your name below to consent.]

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Please enter the last four numbers of your GID (ex. if your number is -02653159, enter 3159).

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What is your year of birth?

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Choose one or more races that you consider yourself to be:

- White
- Black or African American
- American Indian or Alaska Native
- Asian
- Native Hawaiian or Pacific Islander
- Other

What is your gender?

- Male
- Female
- Prefer not to say
- Other

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What is your major?

- Biological Engineering
  - Bio-Resources Engineering
  - Chemical Engineering
  - Civil Engineering
  - Computer Engineering
  - Computer Science
  - Construction Engineering Technology
  - Electrical Engineering
  - Environmental Engineering
  - Industrial Engineering
  - Industrial Technology
  - Mechanical Engineering
  - Mechanical Engineering Technology
  - Other
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What is your estimated graduation date?

- Spring 2020
- Fall 2020
- Spring 2021
- Fall 2021
- Spring 2022

### **Measures of Expectancy, Utility Value, Cost, Interest, and Frequency of Connections**

Please rate the following items based on your behavior in this class. Your rating should be on an 8-point scale.

Completely Disagree (1)	Strongly Disagree (2)	Disagree (3)	Somewhat Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)	Completely Agree (8)
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#### Expectancy Items

1. I know I can learn the material for this class.
2. I expect to do well in this class.
3. I am confident that I will be successful in this class.
4. I am confident I learned the material in this class.

#### Utility Value Items

1. I can apply what we learned in this class to the real world.
2. The course material is relevant to my future career plans.
3. The material in this class is personally relevant to me.
4. I see how what we are studying is important to my future career.
5. The material in this class is useful in my everyday life.
6. Learning the course material will help me achieve my future goals.

Cost Items

1. This semester, I don't have the time to put into this class.
2. Doing well in this class isn't worth all the things that I have to give up.
3. I am unable to invest the effort that is needed to do well in this class.
4. This class requires too much time.
5. Unfortunately, I can't put as much time into this class as I would like.

Interest Items

1. I think the engineering design process is very interesting.
2. I find the engineering design process fascinating
3. I think the engineering design process is an important subject.
4. I am excited about this class
5. I would recommend this class to others.
6. I really enjoy this class.
7. My experience in the course has made me want to take more engineering design courses.
8. To be honest, I just don't find the engineering design process interesting.
9. I think the material in this class is boring.
10. Engineering design fascinates me.

Connection Frequency Items

Please respond the following questions regarding the frequency with which you engage. Your rating should be on a 6-point scale.

Never	Rarely	Sometime	Often	Very often	All of the Time
(1)	(2)	(3)	(4)	(5)	(6)

1. During a regular class period or lecture, how often do you connect the class material to your future career?
2. When doing outside work for this class, how often do you connect the class material to your future career?
3. When studying for quizzes or exams, how often do you connect the class material to your future career?

APPENDIX D

EVALUATION RUBRICS

Table 21: Rubric for assessing Analytical Essay

Analytical Essay Rubric Spring 2020

Criteria	Exemplary 3 points	Satisfactory 2.5 points	Below Satisfactory 2 points	Unsatisfactory 1 point	Criterion Score
Purpose and Thesis/Argument	Clearly and explicitly states the purpose (thesis/argument) of the essay in the opening paragraph.	Indicates the purpose (thesis/argument) of the essay in the opening paragraph but is not explicit.	Vaguely indicates the purpose (thesis/argument) of the essay in the opening paragraph but is not explicit.	Does not indicate, explicit or otherwise, the purpose (thesis/argument) of the essay in the opening paragraph.	/ 3
Support and Citing Sources	Uses sufficient, credible, relevant information from sources to support the argument/thesis. Cites at least 3 sources properly, use of references indicates substantial research, in text citations.	Uses credible and relevant information, but needs some additional information to fully support the argument/thesis. Some research of the topic was done but was inconclusive to support topic, two or less references given, cited properly.	Gathers some credible information but not enough; Some information may be irrelevant. Did little or no gathering of information on the topic, did not cite information, one or fewer references provided.	Relies on insufficient, unreliable or irrelevant information. No research was done, no references provided or correctly cited.	/ 3
Synthesis/perspective	Identifies and accurately explains the relevant key concepts. Original insights to the case study that are relevant and are supported with references.	Generally explains the relevant key concepts, Some original insights with supporting references.	Identifies some (not all) key concepts; Insights are not clear or based on any information other than their own opinions, many unsupported details.	Does not identify key concept or Mimics thoughts from others verbatim or is solely their own unsupported opinion.	/ 3
Organization	Essay is very easy to read. Information is impeccably organized to provide logical, clear basis for argument. Well-structured beginning, body, and conclusion with clear transitions. Critical thinking skills are evident.	Essay is easy to read. Information is mostly organized to provide a logical flow but may need more transitions. Essay is generally focused and stays on topic with relevant ideas.	Essay is somewhat difficult to read. Central point and flow of essay is lost. Essay has basic organization but lacks continuity, ideas are loosely related.	Essay is difficult to read. Information is not organized. No logical flow of argument. No clear purpose and lacks logical progression of ideas.	/ 3

Table 22: Rubric for assessing reflection assignment.  
Individual A-3 Spring 2020

Criteria	Level 3 3 points	Level 2 2 points	Level 1 1 point	Criterion Score
A-3 Format	Looks great; formatted to fit on a single A-3 page; more visual than textual	Did not do one of the three in Level 3	Did not do two of the three in Level 3	/ 3
Writing Fundamentals	Easy to read text, no spelling grammar issues, clearly edited before submission	Somewhat easy to read, some spelling grammar issues, possibly edited before submission	Not easy to read, spelling and grammar throughout, probably not edited before submission	/ 3
Discover	Discusses/shows pertinent physical concepts, includes relevant mathematical equations, shows what was discovered; more visual than textual	Attempts to show physical concepts, equations, but not clear; Attempts to reveal what was discovered, but not clear; more textual than visual	Mixes this step up with another step; does not explain/show underlying principles; no visuals, only text	/ 3
Define	Clearly indicates most important objectives, functions, constraints for discipline specific part of design project	Objectives, functions and constraints are listed, but not clear which are most important to the discipline specific part of the design	Objectives, functions and constraints may not be listed; this design step might be mixed up with another.	/ 3
IPT	Clearly demonstrates (more visually than textually) some aspect of the design that changed between prototype 1 and prototype 2	Demonstrates, possibly more textually than visually, some aspect of the design that changed between prototype 1 and prototype 2	Does not show any change that occurred between proto 1 and proto 2; possibly mixes this step up with another design step	/ 3
Reflection	Illuminates some specific aspect of project management or multi-d teaming that was important to the design process	May illuminate some general aspect of project management or multi-d teaming important to the design process	Does not illuminate anything related to project management or multi d teaming that was important to the design process	/ 3

APPENDIX E

PILOT STUDY FACTOR ANALYSIS

Table 23: Factor loadings for Pilot Study data based on Maximum Likelihood factor analysis with Equimax rotation for 25 items. ( $N = 138$ )

Variable	Factors				
	Interest in Design	Utility Value	Interest in the class	Expect- ancy	Cost
I know I can learn the material for this class.				0.73	
I expect to do well in this class.				0.94	
I am confident that I will be successful in this class.				0.96	
I am confident I learned the material in this class.				0.80	
I can apply what we learned in this class to the real world.		0.78			
The course material is relevant to my future career plans.		0.79			
The material is personally relevant to me.		0.74			
I see how what we are studying is important to my future career.		0.71			
The material in this class is useful in my everyday life.		0.64			
Learning the course material will help me achieve my future goals.		0.65			
This semester, I don't have the time to put into this class.					0.50
Doing well in this class isn't worth all the things that I have to give up.					0.76
I am unable to invest the effort that is needed to do well in this class.					0.88
This class requires too much time.					0.51
Unfortunately, I can't put as much time into this class as I would like.					0.38
I think the engineering design process is very interesting.	-0.86				
I find the engineering design process fascinating	-0.88				
I think the engineering design process is an important subject.	-0.82				
I am excited about this class			0.82		
I would recommend this class to others.			0.83		
I really enjoy this class.			0.82		
My experience in the course has made me want to take more engineering design courses.			0.72		
To be honest, I just don't find the engineering design process interesting.	-0.60				
I think the material in this class is boring.			0.35		
Engineering design fascinates me.	-0.70				

APPENDIX F

TIME 2 FACTOR ANALYSIS

Table 24: Factor loadings for Time 2 data based on Maximum Likelihood factor analysis with Equimax rotation for 25 items. ( $N = 144$ )

Variable	Factors				
	Interest in Design	Utility Value	Interest in the class	Expect- ancy	Cost
I know I can learn the material for this class.				-0.64	
I expect to do well in this class.				-0.86	
I am confident that I will be successful in this class.				-0.90	
I am confident I learned the material in this class.				-0.73	
I can apply what we learned in this class to the real world.		0.60			
The course material is relevant to my future career plans.		0.74			
The material is personally relevant to me.		0.67			
I see how what we are studying is important to my future career.		0.75			
The material in this class is useful in my everyday life.		0.70			
Learning the course material will help me achieve my future goals.		0.71			
This semester, I don't have the time to put into this class.					-0.83
Doing well in this class isn't worth all the things that I have to give up.					-0.76
I am unable to invest the effort that is needed to do well in this class.					-0.78
This class requires too much time.					-0.71
Unfortunately, I can't put as much time into this class as I would like.					-0.59
I think the engineering design process is very interesting.	0.87				
I find the engineering design process fascinating	0.88				
I think the engineering design process is an important subject.	0.74				
I am excited about this class				-0.87	
I would recommend this class to others.				-0.82	
I really enjoy this class.				-0.85	
My experience in the course has made me want to take more engineering design courses.				-0.70	
To be honest, I just don't find the engineering design process interesting.	0.64				
I think the material in this class is boring.				-0.44	
Engineering design fascinates me.	0.73				