The Influences of Engineering Student Motivation on Short-Term Tasks and Long-Term Goals

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THE INFLUENCES OF ENGINEERING STUDENT MOTIVATION ON SHORT-TERM TASKS AND LONG-TERM GOALS

A Dissertation
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy
Engineering and Science Education

by
Adam N. Kirn
August 2014

Accepted by:
Dr. Lisa Benson, Committee Chair
Dr. Geoff Potvin
Dr. Zahra Hazari
Dr. Gautam Bhattacharyya
Abstract

This dissertation describes a sequential explanatory mixed methods study seeking to understand how engineering students’ long-term motivations influence present actions. Although academic performance is the most common indicator of student success, it does not take into account underlying motivations needed for students to effectively apply their intellectual resources.

The first phase of the quantitatively examines the salient features of student motivation (e.g. expectancy, value, and future time perspective) related to students’ long-term goals and short-term tasks. The second phase quantitatively examines what correlations, if any, exist between three factors of students’ motivation (expectancy of success in an engineering major, perceptions of their present as engineering students, and perceptions of their future as engineers) and problem solving performance during an introductory engineering course. The third phase examines motivation profiles of upper-level engineering students in major specific courses to create groups from which to recruit participants.

Results of the first phase indicated that students’ expectancies and perceptions of the future differentiate students with different long-term goals. The second phase indicated that student perceptions of the future are correlated to steps undertaken in engineering problem solutions. Upper-level engineering students were differentiated into groups based on their expectancies, problem solving self-efficacy, and perceptions of the present and future.

In the fourth phase, students were interviewed about their long-term goals and actions taken in the present. This phase extends previous work to include rich descriptions of engineering students’ experiences with their future time perspectives (FTP). Themes from the data indicated some students’ FTPs had goals defined far into the future while others had no specific goals beyond graduation. Highly defined FTPs showed development of plans beyond graduation with high career specificity. Additionally, students’ defined futures assisted in creating higher value for present tasks, and increased performance and persistence on tasks seen as connected. Understanding relationships between student motivation and present action can help engineering
educators increase interest in engineering and prepare students to become effective engineers.

The final phase of this work examines student perceptions of engineering problem solving and how their motivations may influence these perceptions. Results indicate that student perceptions of problem solving may in fact be driven by their motivations across time scales. Additionally, students valuation of engineering problems may be based on student adapted cultural perceptions of engineering problems and not their cones.
Dedication

This work is dedicated to those who have supported my choose your own adventure path to education. To my parents who encouraged a ten year-old to pursue enrollment in an experimental alternative learning program because it was his dream. To my undergraduate advisors who showed me that being different and pushing against the norms can lead to inner happiness. To my graduate advisor who showed me that, while not without its challenges, it is worth the fight to maintain individuality and happiness. Through exploration of and exposure to different ways of approaching education I have been able to reach and achieve my dreams, goals, and desires.
Acknowledgments

I am grateful to my committee, Dr. Lisa Benson, Dr. Geoff Potvin, Dr. Zahra Hazari, and Dr. Gautam Bhattacharyya, for the giving of your advice and time during this process. I am immensely thankful to Dr. Lisa Benson, my advisor and chair of my dissertation committee, for your endless guidance, support, and encouragement throughout this entire process. This experience has been rewarding and beneficial for me, and I could not have been more fortunate than to have you serve as a mentor and ally through it all. I am also appreciative of Dr. Geoff Potvin and Dr. Zahra Hazari for sharing your wealth of knowledge on education research and pushing me to develop my research ideas into reality.

I want the thank the National Science Foundation for Funding NSF CAREER Grant “Student Motivation and Learning in Engineering” (EEC-1055950), NSF IEECI “CU Thinking” (EEC-0935163), and NSF Engineering Education Research Leader Networkshops (EEC-1314725) that influenced this work. Dr. Jennifer Husman for her guidance and mentorship in the field of motivational psychology. Additionally, I would like to thank Allison Godwin for challenging me and helping me grow as a researcher. Without her assistance this work would not have reached the level of depth and clarity that is presented.

Finally, I am deeply and forever grateful to my family and friends who stood by me throughout this time. I am grateful to my partner, Danny Sierra, for constantly encouraging me and supporting me after good days and bad and serving as a copy editor. I am grateful to my parents, Art and Shelly Kirn, for their love and guidance in all facets of my life. To my brothers and sisters, Jeff, Tina, Charles, and Tami, you have been the anchor when needed and the party planning committee when it was time to celebrate. Everyone’s unwavering support and encouragement were the driving force behind by motivation to keep going, especially at those moments when I did not want to.
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Chapter 1

Student Motivation and Problem Solving

The goal of this work was to understand the influence of student motivation across time scales on aspects of problem solving. This goal arose from an initial question seeking to understand how aspects of the affective domain and cognitive domain may influence student performance in the classroom. In order to meet the demands of preparing a larger, more diverse workforce with a wider range of skills, aspects of student motivation and performance must be considered. Despite the implementation of evidenced-based reform practices in a greater number of engineering classrooms, these calls for change and preparedness still exist.

Developing this work required identification and utilization of a series of theoretical frameworks, in order to assess student motivation across multiple time scales and to understand how motivation may be influencing student perceptions of problem solving. In Chapter 2, background exploration of engineering student motivation profiles is conducted to determine the salient motivation frameworks for students’ goals across time scales. The work described in this chapter focused on understanding the motivations of freshman engineering students at a southeastern land grant institution. Results indicated that student populations did not significantly differ on predetermined motivation constructs related to achievement motivation but did show significant differences on singular items. Results indicated that elements of students’ expectations of performance and future perspectives were significantly different among groups of engineering disciplines.

After indication of some student motivation based differences, work in Chapter 3 explored how aspects of student motivation may influence steps taken during student problem solving. This work served as the first exploration of the connections between engineering students’ motivations across time scales and their problem solving performance. Results indicated that student problem solving performance was influenced
by student perceptions of the future. Specifically, students with more detailed perceptions of the future spent more time solving problems, and were more likely to identify unknowns.

These results, while informative, provided limited information to explain how students’ perceptions of future goals may be influencing present actions. To better understand student perceptions of engineering problem solving and their motivations across time scales we sought to recruit participants that would represent a range of motivational profiles. Students were recruited from second-year major specific courses in mechanical and bioengineering. These majors were selected due to programmatic similarities yet differing career goals. Chapter 4 discusses collection of quantitative survey data to understand these students’ motivations across time scales. Results indicated that there were four types of student motivation profiles, with self-efficacy serving as the primary driver of differentiation between student groups. Student perceptions of the future and how they expected to do on engineering course work served to further differentiate the groups.

Students from each of the four groups discovered in Chapter 4 were recruited for further exploration of their motivations across time scales and their perceptions of engineering problem solving. Research described in Chapter 5 sought to qualitatively explore student motivation across time scales. Phenomenological exploration of student motivation sought to further the understanding of the connections engineering students make between their future goals and their present tasks. Analysis demonstrated that the participants possessed three different future time perspectives, conceptualized as differently shaped “cones”: Sugar Cone, Waffle Cone, and Cake Cone. Students with the Sugar Cone time perspective had highly developed perceptions of the future and descriptions of how these futures were influencing present actions. Additionally, these students made connections between present tasks and future goals. Waffle Cone students had develop perceptions of the future but had goals that were in conflict with one another limiting the depth of the cone into the future. Waffle Cones also had connections from future goals to present actions, and from present actions to future goals. Cake Cone students did not describe a future with a high level of clarity. These students were able to see how the present was assisting them in preparation for an infinite number of futures but they were not able to make connections from the future to the present.

Chapter 6 uses these cones, or detailed understandings of student motivation across time scales, to explore how students’ perceptions of engineering problem solving are influenced by their motivations. Results indicated that student perceptions of engineering problems are influenced by their future cones. Sugar Cones who had the deepest definitions of the future wanted linear problems that were well-defined with singular answers. The remaining Sugar Cone participants wanted problems that were more open ended in nature and that allowed them to explore multiple paths or solutions in the context of their future goals. The Waffle
Cone student indicated a desire for problems that were open-ended but also indicated that engineering problems were not bound by context. Cake Cone students indicated that engineering problems were anything and that these problems should be open-ended for them to prepare themselves for their open-ended future. The value that students saw in solving in engineering problems was consistent across cones, possibly indicating that as these students have adapted to the engineering community of practice, and have also adapted values that mirror the engineering community.

This work serves as a means to understand how the affective domain may influence the cognitive domain, and to understand how these two domains work together to drive engineering student performance.
Chapter 2

Exploratory Quantitative Assessment of Engineering Student Motivation

2.1 Introduction

Studies of student retention and learning in engineering have been made in comparison to other majors and colleges within the university system (Ohland et al., 2008). Such studies are often used for implementation of evidence-based educational reform, but one factor limiting the success of such reforms is treating engineering as a monolithic discipline. Differences between cultural dimensions of engineering disciplines, such as a “newer” (software engineering) versus a more established discipline (electrical engineering), have been noted (Godfrey & Parker, 2010). Although studies have identified differences between student attributes in engineering disciplines (Dee, Nauman, Livesay, & Rice, 2002), research on the differences between factors that characterize them in terms of attitudes, behaviors, and practices is lacking.

Additionally, student motivation is often undervalued in comparison to quantitative student performance measures (Liu, Bridgeman, & Adler, 2012). Research into student achievement motivation has shown that a range of such factors can influence student performance on standardized testing (Liu et al., 2012; Duckworth, Quinn, Lynam, Loeber, & Stouthamer-Loeber, 2011) and in course-specific tests (Sundre & Kitsantas, 2004). While the role of student motivation on standardized test scores is well documented, there is a need for research on the effect of subject- or major-specific motivation on performance and learning.
2.2 Theoretical Frameworks

Motivation is a dynamic construct that is linked to student performance in and out of the learning environment. Achievement motivation has focused on the beliefs, goals, and contexts that influence students’ choice of particular academic goals (Eccles & Wigfield, 2002). Achievement motivation has been expressed as the interaction between the expectation of how one will perform on the task and how much one values the task or its outcomes (i.e. Expectancy x Value theory). This theory shows three main beliefs required for motivated action: a) with enough effort, the performance can be achieved, b) if achieved, it will lead to desired outcomes, and c) those outcomes will lead to satisfaction (Eccles & Wigfield, 2002).

Different motivational constructs have been used under the achievement motivation umbrella to examine academic performance. Research in goal orientation has shown that students with mastery orientations often perform better at multiple levels in both learning and professional environments (Hazari, Potvin, Tai, & Almarode, 2010). Mastery orientations are defined as those who pursue learning for the understanding of a concept or the knowledge, as compared to those with a performance orientation who are more concerned with grades or money. The work in goal orientation often does not consider the timeframe that students are operating within, and more often considers goals that are only proximal in time.

Another achievement motivation theory is possible selves, which examines student goals in terms of who they want to become or avoid. Research using this theoretical framework has shown that students with differing perceptions of their future will pursue goals differently (Oyserman, 2004; Oyserman, Brickman, & Rhodes, 2007; Pizzolato, 2007, 2006). Possible selves are defined in three parts: who you ideally think you could be, who you realistically think you can become, and a self that you want to avoid (Markus & Nurius, 1986). Additionally, Husman and Lens have demonstrated the importance of future goals in student achievement with their future time perspective theory posit that the temporal distance of student goals, paired with the perceived instrumentality of a current task, will influence student actions in the present (Husman & Lens, 1999). Using a future time perspective framework, Husman and Lens have shown that students who have stronger academic motivations often have stronger or more detailed perceptions of the future impact of academic goals (Husman & Lens, 1999).
2.3 Research Questions

Using the frameworks of Expectancy x Value, possible selves, and future time perspective this work sought to answer the following questions:

1. What are the fundamental differences between engineering disciplines in terms of student motivation?
2. How is student motivation predictive of student choice of major in engineering?
3. How does student motivation in a first year engineering program predict enrollment in an engineering major?

2.4 Methods and Participants

2.4.1 Instruments

Engineering student motivation was assessed using two instruments: the Motivation and Attitudes in Engineering (MAE A.1) survey and a Beginning of Semester (BOS) survey (Table 2.1). Student self-report of motivation was assessed through a series of Likert-type items. The MAE survey was designed to assess student persistence in engineering, through students’ perceptions of tasks and goals related to the present (“Present”) and future (“Future”) as engineers (Husman & Lens, 1999), and their expectations of successfully completing tasks in their engineering studies (“Expectancy”) (Eccles & Wigfield, 2002). This survey has shown that students with more positive perceptions of the Future are more likely to persist in engineering (Benson, Kirn, & Faber, 2013).

Prior to this work, survey constructs were analyzed for reliability and validity. Additionally, factor analysis results demonstrated that three survey constructs were reliable, with values for Cronbach’s alpha ranging between 0.85 and 0.92. Content validity analysis identified constructs as: Expectancy (Eccles & Wigfield, 2002), attitudes about present tasks/goals in engineering (“Present”), and attitudes about future tasks/goals in engineering (“Future”). The latter two constructs are supported and explained by the Future Time Perspective theoretical framework (Husman & Lens, 1999).

The Beginning of Semester Survey (BOS) used here was originally developed to assess a number of topics of interest to the first year engineering program at a southeastern land grant institution, including reasons why students pursued their majors. As a program evaluation instrument, the BOS was not based on a theoretical framework; however it contains items that shed light on students’ underlying reasons for
pursuing engineering, which can help direct our studies of student motivation. The BOS survey items reflect different aspects of student motivation including goal orientation (DeShon & Gillespie, 2005), possible selves (Oyserman, 2004; Oyserman et al., 2007; Pizzolato, 2007, 2006; Markus & Nurius, 1986), and identity (Hazari, Sonnert, Sadler, & Shanahan, 2010).

| Table 2.1: Beginning of Semester (BOS) Survey Items

| To major in Engineering, you do not need to declare your official major until at least April. However, many of you came into General Engineering with an idea of your intended major. If you had to choose your major today and you could only choose one, it would be: (followed by a list of available majors)
| On a scale of 1 to 10, with 10 being very confident, how confident are you about your choice of major in Question 1?
| Please rank the following reasons you wanted to pursue engineering, on a scale of 1-5, with 1 = no influence, 5 = top reason.
| Family member is an engineer
| I know an engineer who I admire
| Family member / Teacher / Guidance Counselor advised me to pursue engineering.
| More scholarship money available
| I want to prove myself by taking the hardest possible major
| Profession is transferable worldwide
| Opportunities to benefit society
| Good potential salary
| I like the challenge of solving problems
| Good job prospects
| Engineers do interesting work
| I like to design and build things

2.4.2 Participants

Survey responses for this study consisted of the 494 engineering students enrolled in a first year engineering program at a southeastern land grant institution who completed the MAE in the Fall and Spring of the 2009-2010 academic year and BOS in Fall 2009 (n= 494). Both MAE and BOS surveys were given within the first two weeks of the semester. Survey responses from the BOS were used in analysis after they were matched to students who completed the MAE in the Fall and Spring. Students earned extra credit for completion of the two surveys used in this study. Additional data was collected on enrollment of these same students in engineering disciplines the following two years. Students’ major data was then collected in spring 2012 (four semesters later) and used in subsequent analysis.
2.4.3 Research Question 1 Analysis

Data from MAE and BOS survey responses were analyzed to examine whether differences in student attitudes during their first year in engineering were observed based on their engineering major two years later. Majors were grouped as traditional (mechanical, electrical, civil, chemical, and industrial) and interdisciplinary (material science, environmental, computer, ceramic, biosystems, and bioengineering). The majors were split by those with a subject specific section on the Fundamentals of Engineering exam and those without (http://www.ncees.org/exams/fe_exam.php). Traditional majors are well-established and have a well-defined canon of knowledge, while interdisciplinary majors draw from a more emergent body of knowledge. Differences in specific survey items for different types of engineering majors were analyzed to glean information for more in-depth future studies. Binomial logistic regression of MAE and BOS survey data were used to correlate constructs and persistence in engineering.

2.4.4 Research Question 2 Analysis

Attitudes of students declaring bioengineering (BIOE) as a major were compared to those for students declaring majors in low-female enrollment disciplines (mechanical, computer, and electrical) to explore possible underlying reasons for the differences in demographics. BIOE’s were also compared to the combined top engineering majors based on enrollment (mechanical, electrical, computer, civil, chemical, and industrial) (Gibbons, 2009). Of the 494 first year engineering students who completed the survey in their second semester, 64 were female. Comparisons of survey data were made between the overall BIOE population to the total population of each group, and females within each group. Results were analyzed using t-tests assuming unequal variances and \( \alpha = 0.05 \).

2.4.5 Research Question 3 Analysis

Students were divided based on type of major chosen: traditional or interdisciplinary. Pearson correlational analyses were run on both survey instruments to determine if items from each survey were testing related facets of motivation. Binomial logistic regression analysis was used to investigate the relationship between self-reported motivations and declared major. The predictors for the model were factor scores from the MAE survey and individual items from the BOS survey, and the outcome variable was the students’ declared major category.
2.5 Results

2.5.1 Research Question 1 Results

Prior results indicated that students’ attitudes about their future were a significant predictor of continued enrollment in engineering two years later by a factor of 2 ($\beta = 2.01$) (Benson et al., 2013). However, the capability of student attitudes to characterize different engineering majors is limited, as no significant differences between chosen majors were found for any construct. Significant differences were found between traditional and interdisciplinary groups of majors for three items within the Expectancy (E) construct and one item within the Future (F) construct (Table 2.2). These results provide some insight into how student motivation might contribute to persistence in a major, but they do not provide enough insight to explain differences in motivation that may affect student choice of major.

Table 2.2: Motivation, attitudes, and expectancy survey results, on a scale from -2 (strongly disagree) to 2 (strongly agree). Survey items from future (F) and expectancy (E) constructs showed significant differences between traditional and interdisciplinary engineering groups. * indicates $p < 0.05$.

<table>
<thead>
<tr>
<th>Construct</th>
<th>Survey Item</th>
<th>Traditional</th>
<th>Interdisciplinary</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>I am struggling with my college courses. (Reverse coded)</td>
<td>0.274</td>
<td>0.587*</td>
</tr>
<tr>
<td>F</td>
<td>I will use the information I learn in this engineering course in the future.</td>
<td>-0.162</td>
<td>0.130*</td>
</tr>
<tr>
<td>E</td>
<td>I am having to work harder than many of the other students in my classes.</td>
<td>0.928</td>
<td>0.685*</td>
</tr>
<tr>
<td>E</td>
<td>I believe I will receive an excellent grade in this engineering course.</td>
<td>0.639</td>
<td>0.902*</td>
</tr>
</tbody>
</table>

BOS data indicated differences in student perceptions about benefiting society, doing interesting work, and designing and building things (Table 2.3). The combination of differences observed between majors for specific MAE and BOS items creates a clearer picture of differences in student motivation based on engineering majors.

2.5.2 Research Question 2 Results

The capability of student attitudes to predict choice of engineering major is limited, as no significant differences between chosen majors were found for the 3 survey constructs. However, differences in specific survey items were found, and these were used to glean information on differences in attitudes for future
Table 2.3: Beginning of semester survey results. Students were asked to rank the following reasons in response to the question, “Please rank the following reasons you wanted to pursue engineering, on a scale of 1-5, with 1 = no influence, 5 = top reason.” *p < 0.05, **p < 0.001.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Traditional</th>
<th>Interdisciplinary</th>
</tr>
</thead>
<tbody>
<tr>
<td>More scholarship money available</td>
<td>1.638</td>
<td>1.837*</td>
</tr>
<tr>
<td>Opportunities to benefit society</td>
<td>3.554</td>
<td>3.753*</td>
</tr>
<tr>
<td>Engineers do interesting work</td>
<td>3.864</td>
<td>3.692*</td>
</tr>
<tr>
<td>I like to design and build things</td>
<td>4.097</td>
<td>3.515**</td>
</tr>
</tbody>
</table>

studies (Table 2.4). The BIOE population and BIOE females report fewer struggles in their college courses than students in top enrollment majors. All BIOEs are less likely to consider switching majors. BIOE females report having a greater ethical and professional understanding than females in top enrollment majors. BIOE females are more confident in major choice than females of top enrollment majors and underrepresented majors. BIOE females value their grade in their introductory course less than females in underrepresented majors. BIOEs report less support from faculty than students in top enrollment majors.

2.5.3 Research Question 3 Results

Correlational analysis was performed in order to determine which elements of the two surveys may test the same features. For all engineering majors, average Expectancy scores from the MAE survey correlated to the item “I like the challenge of solving problems” from the BOS survey ($\rho=0.23$, $p=0.0026$). The average of Future scores corresponded to the item, “Engineers doing interesting work” ($\rho=0.21$, $p=0.0163$). These findings, while statistically significant, are weakly correlated to each other. No correlations between survey constructs or items were found for students who chose traditional majors, while data for interdisciplinary majors showed a correlation between average Expectancy score and the item “I like the challenge of solving problems” ($\rho=0.40$, $p=0.0026$). This correlation provides evidence that these represent similar motivation attributes.

The binomial logistic regression showed that average Present score, the items “I know an engineer who I admire,” “Good potential salary,” and “I like to design and build things” are significant positive predictors of choosing a traditional engineering major. The items “I want to prove myself by taking the hardest possible major” and “Opportunities to benefit society” were positive predictors of choosing an interdisciplinary major. Odds ratios and significance values are reported in Table 2.5.
Table 2.4: Means of biomedical engineering students compared to students in low female representation and top enrollment majors. * indicates $p < 0.05$

<table>
<thead>
<tr>
<th>Question</th>
<th>BIOE/Low Rep. Entire Pop.</th>
<th>BIOE/Low Rep. Female Pop.</th>
<th>BIOE/Top Enrollment Entire Pop.</th>
<th>BME/Top Enrollment Female Pop</th>
</tr>
</thead>
<tbody>
<tr>
<td>I am struggling with my college courses (Reverse coded)</td>
<td>0.571/0.425</td>
<td>0.631/0.500</td>
<td>0.571/0.303*</td>
<td>0.631/0.155*</td>
</tr>
<tr>
<td>I am considering switching majors (Reverse coded)</td>
<td>1.357/1.119*</td>
<td>1.526/0.700*</td>
<td>1.357/1.058*</td>
<td>1.526/0.911*</td>
</tr>
<tr>
<td>I have an understanding of professional and ethical responsibility.</td>
<td>1.33/1.276</td>
<td>1.580/1.200</td>
<td>1.333/1.272</td>
<td>1.578/1.311*</td>
</tr>
<tr>
<td>I am confident about my choice of major</td>
<td>1.33/1.171</td>
<td>1.473/0.800*</td>
<td>1.33/1.114</td>
<td>1.473/0.822*</td>
</tr>
<tr>
<td>The grade I get in this engineering course will affect my future</td>
<td>0.714/0.0851</td>
<td>0.736/1.200*</td>
<td>0.7143/0.786</td>
<td>0.737/0.778</td>
</tr>
<tr>
<td>I am encouraged and supported in my studies by the engineering faculty</td>
<td>0.690/0.918</td>
<td>0.842/0.500</td>
<td>0.690/1.020*</td>
<td>0.842/1.067</td>
</tr>
</tbody>
</table>

2.6 Discussion

Attributes of student motivation can be correlated to student choice of engineering major. Through students’ self-reporting of factors contributing to motivation such as values, perceptions, expectations and attitudes, we determined the factors that are significant predictors of student major choice. The different aspects of motivation examined here have approximately equal influence on student choice of major, showing that student motivation is multi-faceted and students draw influence from multiple areas of their lives to construct goals and make decisions. The MAE survey was developed to inform student persistence in engineering, and thus not all of its constructs are useful for informing differences in choice of engineering major (Benson et al., 2013). The BOS survey also had items that were not significant predictors of student choice. Due to the limited correlations between items on these surveys, we combined the results to create a more detailed picture of the influences of student motivation. The MAE survey addresses features of motivation pertaining
Table 2.5: Results of a binomial logistic regression with MAE and BOS survey data predicting major choice. *p<0.05, **p<0.01

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>SE</th>
<th>Odds Ratio</th>
<th>P-value</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>2.38</td>
<td>1.093</td>
<td>0.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I know an engineer who I admire</td>
<td>-0.225</td>
<td>0.098</td>
<td>0.799</td>
<td>0.021</td>
<td>*</td>
</tr>
<tr>
<td>I want to prove myself by taking the hardest possible major</td>
<td>0.295</td>
<td>0.113</td>
<td>1.343</td>
<td>0.009</td>
<td>**</td>
</tr>
<tr>
<td>Opportunities to benefit society</td>
<td>0.349</td>
<td>0.12</td>
<td>1.417</td>
<td>0.004</td>
<td>**</td>
</tr>
<tr>
<td>Good potential salary</td>
<td>-0.28</td>
<td>0.128</td>
<td>0.756</td>
<td>0.029</td>
<td>*</td>
</tr>
<tr>
<td>I like to design and build things</td>
<td>-0.329</td>
<td>0.107</td>
<td>0.72</td>
<td>0.002</td>
<td>**</td>
</tr>
<tr>
<td>Average Present score</td>
<td>-0.539</td>
<td>0.213</td>
<td>0.584</td>
<td>0.011</td>
<td>*</td>
</tr>
</tbody>
</table>

to attitudes and achievement.

Although it was not designed based on a particular theory or theories of motivation, the BOS survey has items related to identity, possible selves, and goal orientation. The model showed that perceptions of the present and a good potential salary are all positive predictors of majoring in a traditional engineering discipline. These two factors can be interpreted as an extrinsic or performance goal orientation, as they are all external factors students are mindful of (DeShon & Gillespie, 2005; Hazari, Potvin, et al., 2010). Students with positive perceptions of the present are often described as “good” students who want to maintain the positive perceptions others have of good students (Husman & Lens, 1999). While this perception may be similar to an extrinsic goal, it was unique from these other items in this study. Knowing an engineer is also predictive of choosing a traditional engineering major. Knowing an engineer may give students a vision of an attainable possible self (Oyserman, 2004; Oyserman et al., 2007; Pizzolato, 2007, 2006; Markus & Nurius, 1986). It is also more likely that students would know an engineer from a traditional discipline, as these are more established programs with higher numbers of students in the past than interdisciplinary majors. The desire to design and build things, which also describes traditional engineering major choice, could be based within a mastery orientation (Hazari, Potvin, et al., 2010). Students were asked if they “like” to design and build things; the “like” qualifier on this item prompts students to think about what they inherently enjoy. This can be interpreted within the framework of goal orientation (mastery) or as intrinsic value (P. Pintrich, 2000).
The choice of an interdisciplinary major is positively predicted by students’ expressing a desire to prove themselves in the hardest major possible (an extrinsic reward) and the desire to benefit society. Benefiting society is a goal that can be considered extrinsic or intrinsic, based on the student’s view of how they could benefit society. If a student defines “benefiting society” as making a product that aids a group and makes a profit, this is an extrinsic goal; but if that student wants to make an impact on people without regard for reward, then this would be an intrinsic goal. “I want to prove myself in the hardest major possible” was shown to be predictive of choosing an interdisciplinary major. This item could be interpreted as a performance orientation, which focuses on student concern of doing better than others (P. Pintrich, 2000).

The last statement displays one of the limitations for the items used in the BOS survey, in that there is a lot of room for interpretation by the students, and without a follow-up qualitative study, we cannot fully grasp students’ understanding of benefiting society, or proving oneself in the hardest major. The BOS survey was developed to serve the needs of the first year engineering program, and has not been tested for reliability or validity in terms of how well items align with theoretical frameworks of motivation.

The generalizability of these outcomes for all engineering students is limited. The MAE survey has only proven valid and reliable with students in a first year engineering program at the institution in this study. In addition, the motivation results reported here may be skewed in a positive direction, since in comparison to upper level students, first year students may be more intimidated by a low-stakes survey (Liu et al., 2012). The surveys given can be considered to be low-stakes as they hold little to no personal significance to these students; the extra credit offered to students only encompassed a quarter of a point of their overall grade. The terms “interdisciplinary” and “traditional” are defined based on the Fundamentals of Engineering exam. While this interpretation is justified, there are other methods that could be used to split these majors, such as retention rates (Matusovich, Streveler, & Miller, 2010).

### 2.7 Conclusions and Future Work

We are applying achievement motivation as a framework for characterizing differences in engineering populations by discipline. The findings of the MAE show that students in newer, more interdisciplinary majors struggle less in their courses, value introductory courses less, do not feel they work as hard, and expect better grades than those in established, traditional majors. These results, while important, are limited. The MAE survey was developed to inform student persistence in engineering, and thus its constructs are not as useful for informing differences in choice of engineering major. Additional insights from the informal
BOS showed the importance of making a difference and availability of scholarship money for students in interdisciplinary majors, while engineering work and designing and building things were valued less than for students in traditional majors.

Additionally, BIOE students report an ability to persist past the hurdles of introductory classes, along with a perception of less faculty support than other majors. Females in BIOE may have higher persistence rates based on lower consideration of switching majors and higher confidence in major choice, despite valuing their introductory courses less. Persistence past these hurdles may be explained by greater understanding of professional and ethical responsibility. Findings show more positive attitudes towards the future for female BIOEs.

Finally, a binomial logistic regression was generated in order to predict student choice of major based on motivation. “I know an engineer who I admire”, “Good potential salary”, “I like to design and build things”, and average Present score were all positive predictors of a traditional engineering major. “Opportunities to benefit society” and “I want to prove myself by taking the hardest major possible” are positive predictors of an interdisciplinary major. Pearson correlation tests regarding motivation items and constructs showed no correlations between survey measures that were found to be significant predictors of student major, therefore each item of the model assesses a unique piece of student motivation. These results provide a gateway for further exploration of the motivation factors that influence students’ choice of majors. We have also presented factors that are and are not significant predictors of student major choice, which allows future researchers to begin to narrow down the frameworks that could be applicable to studies in this area. For administrators this work allows for the exploitation of these factors in influencing student decisions. In attempts to reach greater numbers of engineering students, recruiters could use the factors listed here to influence student motivation at the time of major selection. These factors could be considered in classroom instruction through the design of activities or discussions that present the positive aspects of these motivational factors. For policy makers, these results indicate that one unified message about the nature of engineering may not work for all students.

These results also demonstrate the potential limitations of discrete visual analog scale surveys to assess the complexity of student motivation. Despite the limitations of the informal BOS, items in this survey can help identify appropriate frameworks such as intrinsic and extrinsic value (scholarship money), identity formation and possible selves (I like to design and build), and goal orientation (benefiting society). Our results also demonstrate the limitations of Likert-scale surveys to fully assess the complexity of student motivation. These findings will help direct more in-depth qualitative research (i.e. developing interview questions and
quasi-experimental designs). Further elucidation of motivational differences between engineering disciplines will allow for examination of how these differences manifest themselves in terms of student learning. These findings indicate a need to direct more in-depth qualitative research (i.e. developing interview questions and quasi-experimental designs) to fully understand this dynamic and multi-faceted topic.
Chapter 3

Relationships between Engineering Student Motivation and Problem Solving Performance

3.1 Introduction

Motivation is commonly understood to influence academic performance, and is hypothesized to influence the development of cognitive skills such as problem solving. The development of skills, such as knowledge transfer (Bransford & Schwartz, 1999), is becoming more important as engineering educators strive to prepare students to solve global challenges after graduation. Previous work has indicated that students with different long-term goals differ on the following motivational items: desiring to do engineering work, wanting to be an engineer, and earning financial incentives. These results speak to students’ perceptions of the field of engineering as a whole, but not student motivation toward specific long-term goals, or the importance of short-term goals. There is a need to expand studies of knowledge transfer to include engineering students’ motivations and their perceptions of problem solving in learning environments. It is not well understood how long- and short-term goals influence engineering students’ problem solving and vice versa. Understanding motivation and the affective domain of engineering students can help educators better prepare students for post-graduation experiences.
3.2 Theoretical Frameworks

The Motivated Action Theory (MAT, (DeShon & Gillespie, 2005)) provides a theoretical connection between motivation and learning in terms of self-goals, principle goals, goal orientation and actions. However, the MAT model does not specify significant interactions between different model components. This study seeks to empirically test connections between students’ perceptions about themselves and their actions.

3.3 Research Question

Although academic performance is commonly used to gauge student success, it does not take into account underlying motivations needed for students to effectively apply their intellectual resources. This study examines what correlations, if any, exist between three factors of students’ motivation (expectancy of success in the engineering major, perceptions of their present as engineering students, and perceptions of their future as engineers) and problem solving performance during an introductory engineering course. Understanding relationships between motivation and problem solving could help engineering educators increase interest in engineering and prepare students to become effective problem solvers.

3.4 Methods and Data Sources

In this mixed methods study, qualitative problem solving data was quantitized to evaluate relationships between motivation factors and problem solving metrics. Students in a first year engineering program at a southeastern land grant institution completed the Motivation and Attitudes in Engineering (MAE) survey online (n=494) two weeks into a first semester engineering course. Problem solutions were collected from a subset of these students (n = 31) for three well-defined story problems (Jonassen, 2004) that were of appropriate difficulty for first year students. This subset of students consisted of two sections of students enrolled in an introductory course, in which data was being collected as part of a separate study.

3.4.1 Motivation Assessment Data

The MAE survey assesses student motivation along three constructs: expectancy of success in the engineering major, perceptions of present tasks and goals in the engineering program, and perceptions of engineering as it relates to future tasks or goals. These motivation factors were based on achievement motivation
theory. Items measuring the construct of expectancy were based on the work of Eccles and Wigfield (Eccles & Wigfield, 2002), while the latter two constructs are supported by the Future Time Perspective framework (Husman & Lens, 1999). The MAE survey, consisting of 38 Likert-scale items, was tested and validated with first year engineering students (Benson et al., 2013).

### 3.4.2 Problem Solving Assessment Data

Three problems analyzed in this study had a constrained context, included pre-defined elements (problem inputs), allowed multiple predictable procedures or algorithms, and had a single correct answer. All three problems presented students with narratives that embed values needed to obtain a final answer. The first problem involved a three-stage solar energy conversion system and required calculation of the efficiency of the cells in the second stage given input and output values for the first and third stages. The second problem required solving for values of components in a given electrical circuit and subsequently determining an equivalent circuit based on a set of given constraints. The third problem involved hydrostatic pressure calculations for a pressurized vessel and required solving for values within the system, as well as converting between different unit systems. Students completed the first problem prior to the first exam, the second problem prior to the second exam, and the third problem prior to the final.

Early in the semester, students were given problem solving templates that demonstrated how to explicitly document important information, and were told that this documentation was correlated with higher success rates (Grigg & Benson, 2014). Students were not required to explicitly document information for the problems analyzed, though it was expected that highly motivated students would do so. Students completed problems on tablet computers using custom-designed software that digitally records ink strokes and erasures, which can be replayed and coded at any point in the recording (Benson, Grigg, & Bowman, 2011). The software enables codes to be associated with specific ink strokes within the problem solution, even in portions that were later erased. Temporal data is also recorded, allowing calculations of time to completion and relative timing of various activities within the work.

Problem solutions were analyzed using a validated coding scheme (Grigg & Benson, 2014) of cognitive and metacognitive tasks, errors, and strategies. Task codes are based on a theoretical framework used to assess problem solving in mathematics: knowledge access, knowledge generation and self-management (Wong, Lawson, & Keeves, 2002). Error codes were classified as conceptual, mechanical, or management, based on categories found in error detection literature in accounting (Owhoso, 2002). Strategy codes were derived from a subset of strategies that appeared most applicable to story problems from various researchers
(Chi, Feltovich, & Glaser, 1981; Nickerson, 1994; Wankat, 1999). Performance metrics were developed based on these codes to evaluate problem solving processes. Eight performance metrics (six evaluating the quality of various problem solving processes and two evaluating the solution outcome) were selected for this evaluation. Evaluated performance metrics, the students' score calculations, and the problem solving processes they demonstrated are shown in Table 3.1.
Table 3.1: Problem Solving Processes Mapped to Performance Metrics

<table>
<thead>
<tr>
<th>Problem Solving Process</th>
<th>Performance Metric</th>
<th>Score Calculation</th>
<th>Description of Metric Coding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recognize / identify the problem</td>
<td>Explicitly identifying unknown value</td>
<td>Scores = 0 or 1 If (Identify unknowns)&gt;0, Score+1</td>
<td>Students identified the variable or quantity for which they were solving.</td>
</tr>
<tr>
<td>Define and represent the problem</td>
<td>Explicit problem definition</td>
<td>Scores = 0, 0.33, 0.67, or 1 If (Restate problem)&gt;0, Score +0.33 If (Identify assumption)&gt;0, Score +0.33 If (Identify constraint)&gt;0, Score +0.33</td>
<td>Students restated the problem in their own words, identified assumptions, and identified constraints.</td>
</tr>
<tr>
<td></td>
<td>Explicit visual</td>
<td>Scores = 0, 0.5, or 1 If (Draw a picture/diagram)&gt;0, Score+0.5 If (Related variables)&gt;0, Score+0.5</td>
<td>Solution contained a graphic representation of the problem and/or related variables within the problem.</td>
</tr>
<tr>
<td>Develop a solution strategy</td>
<td>Problem solving strategy</td>
<td>Scores = 0, 0.5, or 1 If (Guess and check) or (plug and chug), Score = 0 If (Means-End Analysis) or (Segmentation), Score = 0.5 If (Forward chaining) or (chunking), Score = 1</td>
<td>Overall approach and method students used to solve the problem (e.g. means-ends analysis, problem segmentation, etc.), or an apparent lack of strategy (e.g. plug and chug, guess and check).</td>
</tr>
</tbody>
</table>

Continued on next page
<table>
<thead>
<tr>
<th>Problem Solving Process</th>
<th>Performance Metric</th>
<th>Score Calculation</th>
<th>Description of Metric Coding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organize knowledge about the problem</td>
<td>Explicitly identifying known values and equations</td>
<td>Scores = 0, 0.5, or 1 If (Identify known values) &gt; 0, Score + 0.5 If (Identify equations) &gt; 0, Score + 0.5</td>
<td>Known values and equations were identified, whether or not they were provided in the problem description.</td>
</tr>
<tr>
<td>Monitor progress toward the goals</td>
<td>Sensitivity (Error identification based on signal detection theory)</td>
<td>Range from (0,1)</td>
<td>“Signal to noise” ratio; a measure of how well students recognize and correct errors in their work that takes into account rates of committing errors, correcting errors, and falsely making “corrections” when no errors are actually present. Outcome measures evaluate whether the process is producing the desired results.</td>
</tr>
<tr>
<td>Evaluate the solution</td>
<td>Accuracy of answer</td>
<td>Incorrect = 0, Correct (wrong units) = 0.5, Correct = 1</td>
<td>How well the final answer corresponded to an acceptable outcome.</td>
</tr>
<tr>
<td>Evaluate the solution</td>
<td>Time to completion</td>
<td>(End time) - (Start time)</td>
<td>Lapse of time between the last and first digital Ink stroke.</td>
</tr>
</tbody>
</table>
3.4.3 Statistical Analysis

Correlations between motivation constructs and problem solving performance metrics were analyzed using a Spearman rank-order correlation test, with pairwise p-values. Spearman rank-order correlation transforms non-parametric data into rank order for analysis. Probabilities (p-values) were corrected for multiple inferences using the Holm-Bonferroni method to reduce the possibility of committing a type I error (Holm, 1979), and level of $\alpha=0.05$ was used to determine significance.

3.5 Results and Discussion

Because the three problems had different features, different patterns of performance were observed between them, and thus correlation results were variable across the three problems. Results from the Spearman rank-order correlation tests showed students’ ability to identify unknowns was the only performance measure correlated to motivation, specifically future motivation ($\rho=0.57$, $p=0.0225$). The correlation between these measures could indicate that students who have a more positive attitude towards their future as engineers are more likely to identify what they need to know. This correlation was significant only for the solar efficiency problem; there were no significant correlations between performance measures and motivation in the other two problems. Correlations comparing solution accuracy and time to completion to motivation showed only one significant result: future motivation was correlated to time to completion for the pressure problem ($\rho=0.38$, $p=0.0373$). This correlation was not evident in the other two problems, but it may be an indication that students who have a more positive attitude towards their future as engineers spend more time working through a problem. The results of this work are also supported by previous work in motivation that has indicated higher motivations produce better academic results (Allendoerfer et al., 2012). The interactions between motivation and problem solving are further demonstrated when the results of this work are considered with other results showing that students’ problem solving abilities influence their self-efficacy (Hutchison, Follman, Sumpter, & Bodner, 2006).

The limited findings of this analysis can be attributed to several factors. First, the students’ motivation attributes were assessed at the beginning of the semester, and the problems were given over the course of a semester. Prior MAE survey results showed that at least one of the motivation factors (expectancy) significantly changes over the course of an academic year (Benson et al., 2013). It is possible that correlations exist but were not detected between student motivation at the time they completed the problems and their problem solving performance or outcomes. Second, problems appropriate for first year engineering students must be
guided and structured appropriately for their limited problem solving experience. The depth and variability of students’ cognitive and metacognitive processes are limited for such problems. Attributes of student motivation may be correlated with higher-level cognitive processes, but first year students are either not likely to demonstrate these within the problems included in this analysis, and/or may not have the experience to actually use them. Third, the MAE survey included three attributes of motivation (expectancy, perceptions of the present, and perceptions of the future) that were significant predictors of student persistence in engineering (Benson et al., 2013). These do not encompass other factors that contribute to student motivation (such as identity) or extrinsic factors, such as the desire for job security. Lastly, the sample size was relatively small, so it is possible that other significant correlations would appear with a more robust examination of the population.

While results of this work indicated few significant correlations, the analysis can direct future explorations of the connection between these two domains. One approach is to use more complex and open-ended problems to see higher variability in student responses. Open-ended problems designed to introduce new contexts force students to transfer knowledge gained in previous learning environments to new situations (Bransford & Schwartz, 1999; Lobato, 2006; Rebello et al., 2005a). In particular, Bransford and Schwartz’s transfer model is not concerned about if students are transferring, but how and what students transfer (Bransford & Schwartz, 1999). One method for examining student transfer is the teaching interview, shown in the work of Rebello, Zollman, and Allbaugh (Rebello et al., 2005a). Students are prompted to think about new information that they may not have previously considered. Interviews are coded by examining students’ use of “source tools” (resources that students bring with them to solve the problem), “target tools” (attributes of the situation that students’ identify as relevant), and “work bench” (processes that connect new information learned and previous experience or knowledge). Results of this study show one instance of a target tool (identifying unknowns) as being correlated to students’ perceptions of the future. Open ended problems often prove too difficult for first year engineering students, therefore we will target upper level engineering students (sophomores, juniors and seniors) who have more training and skills to solve problems designed to elucidate knowledge transfer.

Upper level engineering students have also begun to pursue specific courses within their majors that can develop their possible selves (Markus & Nurius, 1986). Engineering is often a poorly defined major for incoming students due to a lack of experience with the field prior to college (Katehi & Pearson, 2009). More complex, open-ended, and less well-constrained problems allow students to explore the complex nature of engineering problems. Improved understanding of what an engineer is and may allow students to form more
defined possible selves. The better definition allows students to form balanced possible selves of what they want to become and what they want to avoid becoming (Oyserman et al., 2007; Pizzolato, 2007, 2006). The creation of this balance is similar to extended future perspective described by Husman and Lens (Husman & Lens, 1999). Both balanced possible selves and extended future perspectives have been shown to increase student success at attaining their future goals, and overcoming the hurdles they may face. Oyserman has shown that students who have well developed possible selves are more likely to take action pursuing college (Oyserman, 2004). Differences in student perceptions of the future leading to differences in action could show up in students in problem solving processes, including transfer. Transfer forces students to rely on previously learned and retained information and apply it to novel situations, which may relate to their future perceptions about being engineers.

3.6 Conclusions

In this work we examined correlations between the affective domain (motivation), and the cognitive output of students (problem solving strategies). Correlation analysis showed few significant correlations between motivation and problem solving strategies for well-defined story problems completed by first year engineering students. This work has shown some of the limitations of quantitatively analyzing correlations between motivation and how students are solving engineering problems, but provides possible ways to move forward to examine how student cognitive and metacognitive processes can be influenced by motivation. Examining students’ perceptions of future and possible selves and correlations between these factors and knowledge transfer while solving open-ended problems is one path that may connect these two domains, allowing us to create a more detailed representation of the student learning experience.
Chapter 4

Quantitative Assessment of Student Motivation for Second Year Engineering Majors

4.1 Introduction

Student motivation is often undervalued in comparison to quantitative student performance measures (Liu et al., 2012) in research that contributes to evidence-based curricular and programmatic changes in higher education. Evidence-based curricular changes in higher education have had limited effect on improving the state of higher education (Haertel, 1999). While lack of improvement in learning may be attributed to limited cognitive effects of the innovations being examined, it is more likely that these minimal learning gains are caused by ignoring student motivation (P. Pintrich, Marx, & Boyle, 1993). Additionally, in engineering, these innovations often neglect the student-based (Dee et al., 2002) and cultural differences (Godfrey & Parker, 2010) between different majors. To enhance education there has been a call in the literature to consider the affective domain of students in addition to academic performance (Belenky & Nokes-Malach, 2012; Husman & Lens, 1999; Liu et al., 2012; P. Pintrich & De Groot, 1990; Ryan & Deci, 2000). One model for understanding how student motivation influences student learning is Motivated Action Theory presented by DeShon and Gillespie (DeShon & Gillespie, 2005). This model posits that students are driven by goals to perform actions. In this model, student goals are situated in different levels or time scales—from goals that
are more long-term and stable, to goals that are situated in the present and are temporary. The combinations of motivations toward short- and long-term goals prompt students to act. While Motivated Action Theory provides a map for student action, it does not signify which paths are significant for actions that will improve student learning.

4.2 Theoretical Frameworks

To understand the significance of paths from long- to short-term goals, we must first understand students’ motivations at each proposed level. Students’ motivations toward long-term goals can be evaluated through Expectancy x Value theory, the expectation of how one will perform on a task, and how much one values a task or its outcomes (Eccles & Wigfield, 2002). Expectancy x Value theory posits that three main criteria must be met for motivated action: a) With enough effort, the performance can be achieved; b) If achieved, performance will lead to desired outcomes; and c) Those outcomes will lead to satisfaction (Eccles & Wigfield, 2002). Work in Expectancy x Value theory has shown that students who have higher expectations will have better academic performance (Jones, Paretti, Hein, & Knott, 2010), and those who see higher value for a task will persist longer (Eccles & Wigfield, 2002). Expectancy x Value theory has been developed to examine students’ motivations toward long-term goals, such as major (Eccles & Wigfield, 2002).

Despite development with long-term goals, Expectancy x Value theory does not provide express consideration of the variable time scales of students’ long-term goals. Not considering the temporal space of students’ goals limits the way in which researchers and practitioners can understand how students’ motivations influence action. Husman and Lens have examined students’ perceptions of the future and how the future relates to present tasks (Husman & Lens, 1999). Future Time Perspective theory posits that the temporal distance of student goals, paired with the perceived instrumentality of a current task, will influence student actions in the present (Husman & Lens, 1999). Husman and Lens have shown that students who have stronger academic motivations often have stronger or more detailed perceptions of the future, which correlates to improved persistence and performance on academic tasks (Husman & Lens, 1999). While this framework explicitly examines students’ long-term goals, it has had limited application in engineering (Husman, Lynch, Hilpert, Duggan, & mary ann Duggan, 2007; Nelson, Husman, Koseler, & Bowden, 2012; Shapcott, Nelson, & Husman, 2012).

While the two frameworks mentioned above explicitly consider students’ motivations toward long-term goals they have not been developed to work with motivations toward short-term goals. Bandura’s work in
Self-efficacy has been developed to examine motivations toward short-term tasks (Wigfield & Eccles, 2000). Self-efficacy speaks to students’ specific perceptions on how they will perform on a task (Bandura, 1977). Self-efficacy has been shown to influence the use of learning strategies on tasks related to students’ courses (Schiefele, 1991). While self-efficacy and expectancy are correlated constructs when examining the same time scale of goals (Jones et al., 2010), self-efficacy was developed to examine short-term tasks that require a high level of granularity (Bandura, 2006). The granularity of self-efficacy makes it more useful for examining motivations toward short-term goals.

4.3 Research Questions

Different aspects of engineering student motivation will be addressed through three research questions: RQ1) What elements of an instrument designed for (and validated with) first-year engineering students are valid for assessing motivation of upper level engineering students? RQ2) How do motivations differ for upper level students in different engineering majors? RQ3) What are the similarities of the motivational profiles of these students?

4.4 Methods

4.4.1 Utilized Theoretical Frameworks

Previous work with engineering students established three motivation factors related to their engineering major (long-term goal): students’ expectancies related to their major, perceptions of future goals and tasks, and perceptions of present goals and tasks (Benson et al., 2013). These factors are based on two motivation theories: Expectancy based on Expectancy x Value theory (Eccles & Wigfield, 2002), and perceptions of future (Future) and present (Present) explained by Future Time Perspective theory (Husman & Lens, 1999). Results indicated that students with higher perceptions of the Future, or having a more positive outlook on their long-term goals, were more likely to persist in engineering than students with lower perceptions of the future (Benson et al., 2013). In other work it has been shown that students with higher expectancies will perform better on academic tasks, and those who value tasks more will persist longer at those tasks (Eccles & Wigfield, 2002). Work in future time perspective has shown that students who have a time perspective (view of time) that is situated further in the future are more likely to persist on tasks that they are currently working on than students who have a view of time that is closer to the present (Husman & Lens, 1999).
In these prior studies, students’ Expectancy, Present, and Future are evaluated in relation to their engineering major, and do not speak to students’ short-term motivations for classroom tasks such as problem solving. To better understand the different elements of student motivation, we are adapting the above framework to include student motivations toward problem solving. A commonly used framework in student problem solving is expert-novice, which compares how students and experts (often faculty) solve problems (Chi et al., 1981; Donovan, Bransford, & Pellegrino, 1999; Sweller, 1988). This framework has been applied across many fields and has helped to elucidate the steps of problem solving that are important for success (Donovan et al., 1999). The expert-novice framework was adapted into a survey and given to students to examine what parts of the problem solving process students would perform (Mason & Singh, 2010). This survey administration, much like others, showed a difference between faculty and graduate students, with faculty more likely to perform expert tasks. However, this survey could not differentiate between successful and unsuccessful students due to the fact that students have yet to become experts during their time in the university system (Ericsson, Charness, Feltovich, & Hoffman, 2006). To assess student motivation in relation to problem solving, and examine the variability between students, the instrument developed by Mason and Singh was modified to examine student views of problem solving using a self-report rating of self-efficacy (Bandura, 2006). Confidence in problem-solving self-efficacy examined alongside motivation toward long-term goals can begin to elucidate the interactions of these two aspects of motivation.

4.4.2 Participants and Instruments

Students enrolled in major-specific second year courses at a southeastern land grant institution in the fall of 2012 participated in surveys assessing their views on motivation related to long-term goals and short-term goals. Bioengineering (BIOE) and Mechanical engineering (ME) students were selected for this study due to the similarities of some of the course content of the two majors, yet dissimilar populations (Gibbons, 2009). Students were given the Motivations and Attitudes in Engineering (MAE) survey, an instrument that assesses student perceptions of their Expectancy, Future, and Present (Benson et al., 2013). This thirty-four question quantitative survey was developed and validated with first year students in a general engineering program at the southeastern land-grant institution. Examples of Expectancy items include, “I expect to do well in this engineering course” and, “I am confident I can do an excellent job on the assignments and tests in this engineering course”. Present items included, “I will use the information I learn in this engineering course in the future” and, “What I learn in my engineering course will be important for my future occupational success”. Future items included, “My interest in engineering outweighs any disadvantages I can think of”,

28
and “I want to be an engineer”. Additional MAE items may be found in Appendix A.1. MAE items are anchored Likert-type items on a seven-point scale from strongly disagree to strongly agree.

An additional set of twenty-three items pertaining to students’ problem solving self-efficacy were also developed. The problem solving items were adapted from the Attitudes and Approaches to Problem Solving survey (Mason & Singh, 2010), and placed on a scale from 0-100 (Bandura, 2006). This change allows us to examine motivation toward problem solving tasks (short-term tasks) that is distinct from motivation related to students’ goal of obtaining an engineering degree (long-term goals) (DeShon & Gillespie, 2005). Samples of problem solving self-efficacy items included “Drawing pictures or diagrams to answer multiple-choice engineering problems” and “Checking my work for errors when I have obtained an unreasonable solution,” after being prompted with “Please rate how certain you are that you can do each of the things listed below”. Additional items from this construct are found in Table 4.1. These items were added to the end of the survey to not influence results of the original MAE items. Students were offered the opportunity to win a ten dollar gift card as incentive for participation. Extra credit was offered to BIOE students, but not to ME students due to departmental policies. A red herring item (“Please respond forty-two to this item.”) was added to the self-efficacy section to determine if students were properly responding to survey items. Five students did not fill out the red herring item correctly and were excluded from analysis.

### 4.5 Analysis

Statistical analyses in this paper were completed using the software R (Team & R Core Team, 2013) and JMP statistical software. An exploratory factor analysis (EFA) was conducted to determine how the MAE survey would factor with a new student population and additional self-efficacy items. Promax rotation was used due to potential correlations of items, and 0.4 was used as the minimum threshold. Confirmatory factor analysis was not conducted due to the novel population and insufficient sample size (Bearden, Sharma, & Teel, 1982). Internal reliability of the survey items was tested through the use of Cronbach’s α (Tavakol & Dennick, 2011). Differences in motivation by major, academic class, grade point average (GPA), sex, ethnicity, and basic skills math test (BST) score were tested by using analysis of variance. The BST is an assessment of students’ pre-calculus abilities at this institution during the first two weeks of students’ first math class. Student scores from the BST were used due to the predictive nature of math preparation on student success (Sadler & Tai, 2001). Differences in GPA between majors were tested using Welch’s t-test. Least squares means contrasts were run to examine the differences between juniors and sophomores and
Table 4.1: Problem solving self-efficacy items on a scale from 0-100. Prior to answering these items students were prompted with, “For the following items, please rate how certain you are that you can do each of the things below by writing the appropriate number.”

<table>
<thead>
<tr>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work through an engineering problem with a peer, when having difficulty solving it alone.</td>
</tr>
<tr>
<td>Go to see a teacher or TA to get help when I am not sure how to start a problem.</td>
</tr>
<tr>
<td>Check my work for errors when I have obtained an unreasonable solution.</td>
</tr>
<tr>
<td>Handle the mathematics involved with solving engineering problems.</td>
</tr>
<tr>
<td>Draw pictures and/or diagrams even if there is no partial credit for drawing them.</td>
</tr>
<tr>
<td>Determine what may be wrong with a problem solution if the answer seems unreasonable.</td>
</tr>
<tr>
<td>After solving engineering problems in which the same principle is applied in different contexts, apply that principle in other situations.</td>
</tr>
<tr>
<td>Identify the engineering principles in the problem before looking for corresponding equations.</td>
</tr>
<tr>
<td>Determine when my answer and/or work is wrong.</td>
</tr>
<tr>
<td>Think about how each term in an equation relates to the an engineering problem I have not seen before.</td>
</tr>
<tr>
<td>Solve challenging engineering problems.</td>
</tr>
<tr>
<td>Reflect on engineering principles that may apply when unsure of the correct approach to solve the problem.</td>
</tr>
<tr>
<td>Solve an engineering problem symbolically before plugging in the numbers.</td>
</tr>
<tr>
<td>Determine which approach is more reasonable, if two approaches to solve an engineering problem gave different answers.</td>
</tr>
<tr>
<td>Explicitly think about the concepts that underlie the engineering problems I solve.</td>
</tr>
<tr>
<td>Draw pictures and/or diagrams to represent the situations described in engineering problems.</td>
</tr>
<tr>
<td>Solve a multiple-choice engineering problem by drawing a picture and/or diagram.</td>
</tr>
<tr>
<td>Learn from the problem solution after I solve each engineering homework problem.</td>
</tr>
<tr>
<td>Keep working on an engineering problem even if I haven’t been able to solve it after 10 minutes.</td>
</tr>
<tr>
<td>Learn enough from my mistakes on tests and homework such that I do not repeat those same mistakes.</td>
</tr>
<tr>
<td>Use different approaches to solve an engineering problem when one does not work.</td>
</tr>
<tr>
<td>Solve an engineering problem with numbers instead of symbols.</td>
</tr>
<tr>
<td>Learn by solving a few difficult problems using a systematic approach.</td>
</tr>
</tbody>
</table>
MEs and BIOEs, since these populations had sufficient numbers for standalone analysis. Least squares mean contrasts separate desired groups from an ANOVA population and test for differences while limiting the influence of the more complicated statistical model. BST score differences were analyzed for class and major using nominal logistic fit, which is used to make predictions with multiple categorical outcomes. In order to determine how students grouped based on motivational profiles, a k-means cluster analysis was conducted. K-means cluster analysis creates groups of similarity by minimizing the distance from the a given number of algorithmic means. The model refines the algorithmic means to create groups of individual data points that are grouped closer to one mean than another (Fraley & Raftery, 1998).

4.6 Results

Of the possible 331 students in the two courses there were 153 survey responses (46.22%), with 44 of the 195 ME students (22.56%) and 79 of the 88 BIOE students (89.77%) responding. Of the total respondents, 32.03% were female (40.5% of BIOE students and 15.91% of ME students). The sample was composed of 85.62% White Non-Hispanic, 3.27% Black or African American, 2.61% Asian, 1.31% Hispanic, 5.88% other, and 1.31% non-responding about their ethnicity. The sample had one freshman, one hundred sophomores, forty-five juniors, six seniors, and one graduate student. EFA results for this population (Table 4.2) indicated that factors of the MAE were similar to previous administrations with first year engineering students (Benson et al., 2013). Three items within Expectancy (“I am certain I can understand the most difficult material presented in the readings for this engineering course”, “The course work in engineering classes is easy”, and “I am having to work harder than many of the other students in my classes”), four items within Present (“I am having fun in my major”, “I get satisfaction from my coursework”, “I am encouraged and supported in my studies by the engineering faculty”, and “My overall attitude about my engineering department is positive”) and six items within Future (“I like the professionalism that goes with being an engineer”, “I feel pride when I tell others that I am an engineering major”, “I must pass my engineering course in order to reach my academic goals”, “Engineers are respected by society”, “I have an understanding of professional and ethical responsibility”, and “The grade I get in this engineering course will affect my future”) did not factor in this analysis and were dropped from subsequent analysis. Self-efficacy items factored into a single construct, showing that students view the different aspects of problem solving as one process. One item from the problem solving self-efficacy section of the survey did not factor (“Handling the mathematics involved with solving engineering problems”) and was excluded from the analysis. Cronbach’s $\alpha$ were 0.93, 0.86,
0.90, and 0.95 for Expectancy, Present, Future, and Problem Solving Self-Efficacy, respectively.

Table 4.2: Results of Exploratory Factor Analysis from Upper-Level Engineering Students in their first major specific course. The survey included Motivation and Attitudes in Engineering items and problem solving self-efficacy items.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Item</th>
<th>Factor Loadings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expectancy</td>
<td>I believe I will receive an excellent grade in this engineering course.</td>
<td>0.93</td>
</tr>
<tr>
<td>Cronbach’s α=0.93</td>
<td>I am struggling with my engineering courses. (Reverse coded)</td>
<td>0.59</td>
</tr>
<tr>
<td></td>
<td>Considering the difficulty of this engineering course, the teacher, and my skills, I think I will do well in this engineering course.</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td>I am certain I can understand the most difficult material presented in the readings for this engineering course.</td>
<td>0.63</td>
</tr>
<tr>
<td></td>
<td>I expect to do well in this engineering course.</td>
<td>0.97</td>
</tr>
<tr>
<td></td>
<td>I am confident I can do an excellent job on the assignments and tests in this engineering course.</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>I am certain I can understand the most complex material presented by the instructor in this engineering course.</td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td>I am certain I can master the skills being taught in this engineering course.</td>
<td>0.79</td>
</tr>
<tr>
<td></td>
<td>I am confident I can understand the basic concepts taught in this engineering course.</td>
<td>0.59</td>
</tr>
<tr>
<td></td>
<td>I am struggling with my college courses. (Reverse coded)</td>
<td>0.45</td>
</tr>
<tr>
<td>Perceptions of Present</td>
<td>I will use the information I learn in this engineering course in the future.</td>
<td>0.82</td>
</tr>
<tr>
<td>Cronbach’s α=0.86</td>
<td>I will use the information I learn in my engineering course in other classes I will take in the future.</td>
<td>0.79</td>
</tr>
<tr>
<td></td>
<td>My course work is preparing me for my first job.</td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td>What I learn in my engineering course will be important for my future occupational success.</td>
<td>0.77</td>
</tr>
</tbody>
</table>

Continued on next page
Table 4.2 – continued from previous page

<table>
<thead>
<tr>
<th>Factor</th>
<th>Item</th>
<th>Factor Loadings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Future</td>
<td>I will not use what I learn in this engineering course. (Reverse coded)</td>
<td>0.69</td>
</tr>
<tr>
<td></td>
<td>The university is preparing me well to become an engineer.</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>I am having fun in my major.</td>
<td>0.41</td>
</tr>
<tr>
<td>Motivation</td>
<td>I am confident about my choice of major.</td>
<td>0.69</td>
</tr>
<tr>
<td></td>
<td>I want to be an engineer.</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>My interest in engineering outweighs any disadvantages I can think of.</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>I am considering switching majors. (Reverse coded)</td>
<td>0.69</td>
</tr>
<tr>
<td></td>
<td>Engineering is the most rewarding future career I can imagine.</td>
<td>0.46</td>
</tr>
<tr>
<td>Problem Solving</td>
<td>Work through an engineering problem with a peer, when having difficulty solving it alone.</td>
<td>0.51</td>
</tr>
<tr>
<td>Self-Efficacy</td>
<td>Check my work for errors when I have obtained an unreasonable solution.</td>
<td>0.58</td>
</tr>
<tr>
<td></td>
<td>Handle the mathematics involved with solving engineering problems.</td>
<td>0.57</td>
</tr>
<tr>
<td></td>
<td>Draw pictures and/or diagrams even if there is no partial credit for drawing them.</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td>Determine what may be wrong with a problem’s solution if the answer seems unreasonable.</td>
<td>0.82</td>
</tr>
<tr>
<td></td>
<td>After solving engineering problems in which the same principle is applied in different contexts, apply that principle in other situations.</td>
<td>0.78</td>
</tr>
<tr>
<td></td>
<td>Identify the engineering principles in the problem before looking for corresponding equations.</td>
<td>0.78</td>
</tr>
<tr>
<td></td>
<td>Determine when my answer and/or work is wrong.</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>Think about how each term in an equation relates to an engineering problem I have not seen before.</td>
<td>0.82</td>
</tr>
<tr>
<td></td>
<td>Solve challenging engineering problems.</td>
<td>0.74</td>
</tr>
</tbody>
</table>

Continued on next page
Table 4.2 – continued from previous page

<table>
<thead>
<tr>
<th>Factor</th>
<th>Item</th>
<th>Factor Loadings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflect on engineering principles that may apply when unsure of the</td>
<td>Correct approach to solve the problem.</td>
<td>0.89</td>
</tr>
<tr>
<td>correct approach to solve the problem.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solve an engineering problem symbolically before plugging in the</td>
<td></td>
<td>0.64</td>
</tr>
<tr>
<td>numbers.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Determine which approach is more reasonable, if two approaches to</td>
<td></td>
<td>0.65</td>
</tr>
<tr>
<td>solve an engineering problem gave different answers.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explicitly think about the concepts that underlie the engineering</td>
<td></td>
<td>0.76</td>
</tr>
<tr>
<td>problems I solve.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Draw pictures and/or diagrams to represent the situations described in</td>
<td></td>
<td>0.62</td>
</tr>
<tr>
<td>engineering problems.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solve a multiple-choice engineering problem by drawing a picture</td>
<td></td>
<td>0.58</td>
</tr>
<tr>
<td>and/or diagram.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learn from the problem’s solution after I solve each engineering</td>
<td></td>
<td>0.64</td>
</tr>
<tr>
<td>homework problem.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learn enough from my mistakes on tests and homework so that I do not</td>
<td></td>
<td>0.58</td>
</tr>
<tr>
<td>repeat those same mistakes.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use different approaches to solve an engineering problem when one</td>
<td></td>
<td>0.82</td>
</tr>
<tr>
<td>does not work.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solve an engineering problem with numbers instead of symbols.</td>
<td></td>
<td>0.52</td>
</tr>
<tr>
<td>Learn by solving a few difficult problems using a systematic approach.</td>
<td></td>
<td>0.72</td>
</tr>
<tr>
<td>Keep working on an engineering problem even if I havent been able to</td>
<td></td>
<td>0.46</td>
</tr>
<tr>
<td>solve it after 10 minutes.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For each construct, items were averaged and this average score was used for subsequent analysis. A non-weighted average was used due to the imposed cutoff when conducting an EFA and the weights possibly giving rise to overvaluing remaining items. ANOVA results showed that students in different academic classes have significantly different expectancies (Table 4.3). Students’ with higher GPAs also have significantly higher expectancies and problem-solving self-efficacy. No significant differences were seen based on major,
sex, ethnicity, and BST both for motivation constructs and GPA.

Table 4.3: Significance values for motivation by major, academic class, GPA, sex, race, and BST score. P-values reported and * indicates $p < 0.05$.

<table>
<thead>
<tr>
<th>Motivation Factor</th>
<th>Expectancy</th>
<th>Present</th>
<th>Future</th>
<th>Problem Solving Self-Efficacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Descriptor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major</td>
<td>0.0770</td>
<td>0.1679</td>
<td>0.4792</td>
<td>0.4469</td>
</tr>
<tr>
<td>Academic Class</td>
<td>0.0198*</td>
<td>0.3273</td>
<td>0.6232</td>
<td>0.2853</td>
</tr>
<tr>
<td>GPA</td>
<td>&lt;0.0001*</td>
<td>0.3439</td>
<td>0.1369</td>
<td>0.0289*</td>
</tr>
<tr>
<td>Sex</td>
<td>0.3188</td>
<td>0.9872</td>
<td>0.938</td>
<td>0.6527</td>
</tr>
<tr>
<td>Race</td>
<td>0.8723</td>
<td>0.9889</td>
<td>0.6763</td>
<td>0.866</td>
</tr>
<tr>
<td>BST</td>
<td>0.0808</td>
<td>0.9527</td>
<td>0.8364</td>
<td>0.6095</td>
</tr>
</tbody>
</table>

Due to confounding from limited numbers of students in academic classes (senior, freshman, and graduate) and majors (non-BIOE/ME), least square means contrasts were run to compare MEs and BIOEs as well as sophomores and juniors (Table 4.4). On a scale of 1 – 7, BIOEs have significantly higher expectancies (5.28) than MEs (4.83). Juniors showed significantly higher expectancies (5.53) and perceptions of the present (5.94) than sophomores (4.91, 5.61 respectively). There are differences in GPA based on academic class ($p=0.04$), with juniors (3.51) having a significantly higher GPA than sophomores (3.34).

Table 4.4: Least square means contrasts between BIOE and ME students and junior and senior students’ motivations. P-values reported and * indicates $p < 0.05$.

<table>
<thead>
<tr>
<th>Motivation Factor</th>
<th>Expectancy</th>
<th>Present</th>
<th>Future</th>
<th>Problem Solving Self-Efficacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comparison</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BIOE v. ME</td>
<td>0.0184*</td>
<td>0.426</td>
<td>0.978</td>
<td>0.146</td>
</tr>
<tr>
<td>Junior v. Sophomore</td>
<td>0.0010*</td>
<td>0.0413*</td>
<td>0.3067</td>
<td>0.0956</td>
</tr>
</tbody>
</table>

A scree plot of the data indicated that there were four groups in this data set (Figure 4.1). The number of groups in a scree plot is indicated by a change in slope in the plotted line. A visual representation of the four groups based on student motivation profiles is shown in Figure 4.2. The four groups when described by their motivational profiles are: Group 1- Highly confident with clear goals, Group 2-quite confident with fairly clear goals, Group 3- somewhat confident with fairly clear goals, and Group 4-not confident without clear goals. The group descriptions were generated relative to one another and not to an absolute reference. The mean values of each construct and descriptions for each group are shown in Table 4.5. The breaking of groups is most strongly driven by student self-efficacy scores, with motivations related toward long-term goals distinguishing between groups with similar levels of self-efficacy.
Figure 4.1: The change in slope of the scree plot indicates that the necessary clusters should be four.

Table 4.5: Detailed descriptions of the students within each cluster, based on responses to the modified Motivations and Attitudes in Engineering survey. Group descriptions were generated relative to one another.

<table>
<thead>
<tr>
<th>Group</th>
<th>E</th>
<th>P</th>
<th>F</th>
<th>SE</th>
<th>GPA</th>
<th>Number of Students</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>5.77</td>
<td>6.48</td>
<td>6.26</td>
<td>92.76</td>
<td>3.45</td>
<td>37</td>
<td>Highly confident, clear goals</td>
</tr>
<tr>
<td>Group 2</td>
<td>5.45</td>
<td>5.72</td>
<td>5.38</td>
<td>84.49</td>
<td>3.58</td>
<td>50</td>
<td>Quite confident, fairly clear goals</td>
</tr>
<tr>
<td>Group 3</td>
<td>4.93</td>
<td>5.57</td>
<td>5.51</td>
<td>74.63</td>
<td>3.34</td>
<td>43</td>
<td>Somewhat confident, clear goals</td>
</tr>
<tr>
<td>Group 4</td>
<td>3.98</td>
<td>4.98</td>
<td>5.03</td>
<td>59.04</td>
<td>3.24</td>
<td>18</td>
<td>not confident, no clear goals</td>
</tr>
</tbody>
</table>
Figure 4.2: The four shaded areas indicate the four different clusters with the numbers indicating a unique student identification number. A k-means cluster analysis was used to create this clustering pattern.

These two components explain 81.98% of the point variability.
4.7 Discussion

EFA results have shown that the MAE can be used with upper-level students with minimal modification. The results of the EFA are similar to previous administrations where the factors were Present, Future, and Expectancy (Benson et al., 2013). Cronbach’s α’s for this study are all within the good to excellent ranges, indicating internal consistency of the items (Tavakol & Dennick, 2011). Problem solving self-efficacy broke out as its own factor, indicating that students view it separately from long-term goals, such as major related expectancy which has been shown to be correlated to major related self-efficacy (Jones et al., 2010). Problem solving self-efficacy as a single factor may indicate that students view problem solving as one step or hurdle instead of a series of subcomponents. Given students’ prior experiences with problem solving they may be chunking the steps of solving a problem together (Chi et al., 1981; Donovan et al., 1999). Additionally, students may be viewing the short-term task of problem solving as one hurdle instead of a series of barriers due to having time perspective set in the future (Husman & Lens, 1999). Results have indicated differences between academic classes on expectancy and perceptions of the present. Differences in self-efficacy and expectancy were noted for students with higher GPAs. The influence of self-efficacy and expectancy on GPA mirrors the work of Jones and colleagues that showed that both factors are predictive of GPA (Jones et al., 2010). While self-efficacy and expectancy have been shown to be correlated in previous work (Jones et al., 2010), these factors are potentially viewed as unique by students due to different time scales of motivations toward obtaining a degree and motivations toward solving a problem (Husman & Lens, 1999). This interpretation is further supported by our comparison of junior and sophomore students: despite juniors having significantly higher GPAs than sophomores, there is not a significant difference in their problem solving self-efficacy. Students with higher problem solving self-efficacy may have had more instances of mastering problem solving in the past (Hutchison-Green, Follman, & Bodner, 2008). Students with higher GPAs may have had more recognition of their mastery of problem solving, thus their higher self-efficacy. Higher perceptions of the present may indicate that students have a better developed time perspective and value their course materials more (Husman & Lens, 1999). More positive perceptions of the present may also speak to increased persistence within the major and tasks related to the major (Benson et al., 2013).

Differences in present and future perceptions for all academic majors are potentially masked due to limited numbers of students in majors outside of BIOE and ME. Lack of differences between sexes and ethnicities may indicate that students who make it to major-specific courses have similar motivation profiles. BST scores while predictive of student performance, are not predictive of differences in student motivation for
this population. The lack of differences between sexes may indicate that the instrument measures presented here are separate from other pieces of motivation, such as intrinsic and extrinsic motivation which have indicated sex-based differences in other work (Kasser & Ryan, 1996), or that students who have progressed this far in their academic careers possess similar motivational profiles regardless of sex. The same explanation also applies for the lack of differences between races. The MAE survey used in this study has demonstrated that students who persist in engineering possess similar motivation profiles when compared to those who leave engineering (Benson et al., 2013). The lack of sex differences reported here is also in contrast with results presented by Hutchinson-Green and colleagues that have indicated that females have lower self-efficacy than males in general engineering courses (Hutchison-Green et al., 2008). This difference may be due to the major-specific context in which students were surveyed influencing results. Items in the context of a students’ major may better relate to their long-term goals which may lead to better performance on tasks and increased self-efficacy (Husman & Lens, 1999; Hutchinson-Green et al., 2008). The increased time of enrollment may also allow students to develop an understanding of what their abilities are and what they are truly capable of doing.

The results of this work support the theory of DeShon and Gillespie, showing that students’ motivations toward multiple goals are at play. The results of the cluster analysis supports the idea of interconnected levels of motivation, and provides grounds for further explanation. A student’s goal of being a high performer, manifested through a strong GPA, may be influencing their expectations toward their major and their problem-solving self-efficacy. The group of students who have higher GPAs are also likely to be juniors who see more usefulness for their current courses in terms of reaching their goals. The interplay of motivations related to long- and short-term goals displayed through the multiple motivations that students possess could explain different actions taken by students throughout their education. These results support the Motivated Action Theory’s idea of multiple levels of motivations playing into student action.

Previous work in motivation has demonstrated that students’ motivational states can be influenced through instruction (Belenky & Nokes-Malach, 2012, 2013; Husman & Lens, 1999). Despite the fact that these motivational states have been produced in laboratory environments, they have been shown to lead to improved learning strategy use (P. R. Pintrich, 1999) and knowledge transfer (Belenky & Nokes-Malach, 2012). While motivation cannot be entirely influenced by instruction (DeShon & Gillespie, 2005), the ability to lead students into positive motivational states could result in student actions that are more beneficial to their learning. Additionally, these results indicate that students’ motivations toward short- and long-term goals/tasks are at play concurrently and may be driving student actions.
4.8 Conclusions

Results of this work show that the Motivations and Attitudes in Engineering Survey can be applied to student populations who have advanced beyond the first year of their studies and can be used for differentiating student groups. Results indicate that students’ perceptions of the present, perceptions of the future, major-related expectancies, and problem-solving self-efficacy are distinct pieces of students’ motivations. These four aspects of motivations examine student perceptions of long- and short-term tasks/goals. Students who have progressed further toward completion of their major show higher expectancies than students who have made less progress, despite being in the same required courses. Additionally, juniors have shown higher perceptions of the present, potentially indicating better understanding of what they want to do, compared to sophomores. Students with higher GPAs also possess significantly higher expectancies and problem-solving self-efficacy. BIOE students have also been shown to have higher expectancies than ME students. Understanding these differences in student motivations, despite the similar entry requirements for students, can help better direct instructional change that can help motivate students in ways that are more beneficial for learning.

4.9 Future Work

Results from this quantitative analysis only speak to a small set of motivational factors that can drive students to perform. As such, future work must consider additional frameworks to describe the motivation of students pursuing engineering degrees and solving engineering problems. While we have a better understanding of how different student characteristics influence student motivation, we have yet to connect these motivations to students’ actions toward learning. Here students have considered their ability to perform during the different steps of a problem as one motivational construct. The types of problems and key features of the problem solving process as viewed by students were not clearly understood, as indicated by the single problem solving self-efficacy factor. Understanding the types of problems and problem features that students notice under the influence of different motivation profiles is not well understood. To gain further understanding of students’ motivations toward problem solving (short-term tasks) and major (long-term goals) participants will be purposefully selected for interviews from the established clusters. These interviews will qualitatively examine students’ motivations toward long-term goals (major and future careers), short-term tasks (problem solving situations), and how the interactions of these two motivations influence student action. An understanding of how motivations influence student action will allow for the creation of interventions
that can influence student motivations related to the learning, retaining, and using of information presented in the learning environment.
Chapter 5

Phenomenological Analysis of Students’ Motivations Related to Short-Term Tasks and Long-Term Goals

5.1 Introduction

Student motivation in engineering is often studied at one of two time scales: short-term task-specific motivation and motivation towards long-term goals. Task-specific motivation seeks to understand student motivation for performing and completing a specific task, such as problem solving or design (Carberry, Lee, & Ohland, 2010). Specifically, students with higher problem solving self-efficacy (a task-specific motivation construct (Bandura, 2006)) have been shown to have improved learning and understanding in introductory engineering courses (Hutchison et al., 2006). Students’ long-term motivation focuses on goals such as graduating with an engineering degree. Work in Expectancy x Value theory has shown that students who have higher expectancies for their courses are significantly more likely to have higher grade point averages (GPAs) (Jones et al., 2010; Matusovich et al., 2010). The importance of both scales in the literature has been highlighted in a number of studies (e.g. (Brown, Finelli, & Neal, 2008; Matusovich, Streveler, Loshbaugh, Miller, & Olds, 2008; Marra, Rodgers, Shen, & Bogue, 2009)). It has been proposed that these two scales of motivation are connected and influence one another (DeShon & Gillespie, 2005). Attempts to connect these scales of motivation have had limited documentation in the engineering education literature (Husman & Lens, 1999).
The purpose of our research is to understand the connection between multiple levels of student motivation and how these levels influence students’ actions and performance.

For this work, we sought to richly describe student experiences with future-oriented long-term goals (e.g. careers) and present tasks, to understand how student perceptions of their futures interact with tasks they perform in the present (task-specific motivation). By addressing this research objective through exploratory qualitative methods, we can further the body of knowledge concerning the complexities of engineering student motivation and its influence on performance and learning in the present.

5.2 Theoretical Frameworks

Literature on student perceptions of the future informs our study and aids in interpretation of our data. Aspects of engineering student future perspectives provide insight into how students’ motivation toward long-term goals may be connected to motivation and action related to short-term tasks. We first turn to literature that conceptualizes how students’ perceptions of the future may influence their present motivation. Additionally, we utilize literature that explains how students use multiple perceptions of the future to refine their future goals and influence their present actions.

5.2.1 Future Time Perspective

Future time perspective has been used to understand how varying perspectives of the future can influence present action (Husman & Lens, 1999). There are three dimensions to one’s future time perspective. The first dimension is time orientation, which can range from being past-oriented to being future-oriented. Students who are future oriented have goals and are primarily focused on the future, and what is yet to come. In establishing these future goals, students incorporate their future desires into the present through motivational goal setting. Students without established future goals have shown greater difficulty anticipating the implications of present tasks for their futures. Additionally, students with more detailed future perspectives that delve further into the future will place more value on future tasks than those with limited or shorter future time perspectives. It has been shown that students who place more value on the future are more likely to possess a mastery orientation (Husman, Shell, & Just, 1996). Possession of mastery orientations has been associated with the use of processes that promote learning and retention (Belenky & Nokes-Malach, 2012).

The second dimension of future time perspective is that of endogenous versus exogenous instrumentality. Students view current tasks based on their established future goals, and determine the value of a task
for both the present and their future goals (Miller, 1999; Husman, Derryberry, Crowson, & Lomax, 2004). Perceived instrumentality is task-specific, and highly dependent on an individual’s future time perspective. Instrumentality is similar to utility value in the Expectancy x Value literature (Eccles, 1984). Students who see the usefulness or instrumentality of a task have shown increased performance in academic settings. A task may be perceived as endogenous or exogenous instrumentality by students. A task that is endogenously instrumental is one that a student views as essential for their desired future, while a task that is exogenously instrumental is one that a student must complete to reach their desired goal, but does not help them make gains relative to that goal (Husman et al., 2004).

The third dimension is based on students’ perceptions of time. Some students perceive time as having the ability to make things better; these students possess a positive view of time. Others who possess a negative view of time do not see the future as a place where things will get better. For students with a positive view of time, helping them make connections to the future may assist in their ability to see the value in present tasks. When possessing a negative view of time, students will not connect items to the future, and will often fail to see the value or have decreased motivation in the tasks they are currently performing (Husman & Lens, 1999; Raynor, 1969).

When combined, these three dimensions of a student’s future time perspective can be conceptualized as forming three axes. Referring to Figure 5.1, a student’s perspective of time rests on the x-axis, and this perspective can range from focused on the past to focused on the future. On the z-axis is the instrumentality of the current task. Because a majority of tasks contain multiple subcomponents in engineering, we hypothesize that students’ motivations fall into an area that is both endogenous and exogenous depending on the specifics of the task and how they are perceived relative to a student’s future goals. On the y-axis is a student’s view of time as either positive or negative.

5.2.2 Possible Selves

Work in future time perspective has indicated that students’ time perspectives and their perceived instrumentality are not enough to sustain academic motivation and interest (Husman & Lens, 1999). The theory of future possible selves rests on the conceptualization that someone can envision themselves in the future. Possible selves is the cognitive manifestation of goals, hopes, fears, and threats. These manifestations by students may aid in sustaining academic motivation and interest. Specifically, three types of possible selves have been found to be important to individuals’ motivations in the present. The first is an ideal possible self. This is the self that can exist if the individual could choose everything that happened to one’s self. An
example of an ideal self would be becoming the first astronaut to land on Mars and return. The second is the attainable self. This version of the future is shaped by who an individual thinks they can become given the life experiences that they have had. For the same person with the ideal self of becoming an astronaut, their attainable self could be becoming someone who designs materials for the shuttle because they are too tall to fit inside the spacecraft. The third is the avoided or feared self. This is the self that individuals know they do not want to become. In the possible selves literature, the avoided self is often depicted as someone suffering from drug addiction or remaining in the same difficult living conditions. Students who possess ideal or attainable possible selves have something to strive for and something to work towards (Markus & Nurius, 1986). The combination of a student’s future time perspective and possible selves can create what our research team has termed a ‘future cone’, as shown in Figure 5.1.

![Figure 5.1](image-url)

Figure 5.1: A theoretical student is represented in this figure who is future-oriented with a positive time perception, and sees both endogenous and exogenous instrumentality in the current task he or she is undertaking.

Much like students with detailed future perspectives, students with ideal selves are more likely to persist when faced with challenges or difficulties in their lives (Pizzolato, 2006). It has been found that balanced possible selves, having both desired and feared possible selves, within a given area are motivationally more effective than unbalanced possible selves (Oyserman, 2004; Oyserman et al., 2007). Additionally, thinking about the future or working to develop future possible selves has been shown to increase interest and efficacy to succeed in school (Oyserman et al., 2007). While possible selves has been shown to influence self-regulatory action (Oyserman, 2004), it, like future time perspective, has been shown to fall short at sustaining
motivation when in conflict with other self-concepts (Oyserman, Bybee, & Terry, 2006). Kerpelman and colleagues proposed a model for adolescents’ identity formation through the exploration of possible selves (Kerpelman & Pittman, 2001). This model demonstrated that environmental feedback leads to varied student responses based on the quality of prior exploration of these selves.

For our work, we adapt the ideas of future time perspective (Husman & Lens, 1999), possible self exploration (Markus & Nurius, 1986), and environmental feedback (Kerpelman & Pittman, 2001) to understand how engineering students, who are in a feedback-intensive environment, use possible selves to clarify their future time perspectives, and subsequently how these future time perspectives lead to refinement of their possible selves and present actions.

5.3 Methods

For this work, students at a southeastern land grant institution were interviewed during the spring and fall of 2013 about their desired future careers, problem solving methods, and the interaction between their desired futures and present tasks (e.g. problem solving). Students were recruited from second year mechanical and bioengineering major specific courses through in-class announcements and emails for a period of three weeks. A second round of recruiting was conducted during the following fall semester in a third year bioengineering course for a period of three weeks using in-class announcements and emails. Bioengineering and mechanical engineering courses were selected for this work to represent a range of differences in post-graduation norms (e.g. medical school vs. industry, respectively). Students were given a twenty-dollar gift card for participation in the interviews.

Nine students were interviewed, which included five students who had just completed their second year of engineering courses and four students who were beginning their third year. Those ending their second year were interviewed during the end of the spring semester (two male mechanical engineers, a female mechanical engineer, a female materials science and engineering major, and a female bioengineer), while those in their third year were interviewed during the beginning of the fall semester (all bioengineers). Eight of the nine students were Caucasian, one student was of African descent. Additionally, two students were of international origin. Racial and ethnic status is not attached to specific students in order to protect the identities of participants. All names used for participants are pseudonyms.

The semi-structured interviews, detailed in Appendix D, were broken into three parts; student desired futures, student perceptions of problem solving, and student beliefs about how these two categories
influence one another. Interviews ranged from 39 to 95 minutes in length. Student responses to a pre-determined set of prompts were used by the research team to guide conversation during the interviews. Additional questions were posed by the interviewers as needed for clarification and further descriptions within student responses.

A phenomenological lens was adopted to collect and analyze the data. Phenomenology’s rich history creating powerful understandings of participants motivations and actions (Lester, 1999) facilitates our ability to establish connections between students’ future-oriented motivations and present actions, through the students’ eyes. The phenomenon of interest for this study, connections between students’ future-oriented motivations and present actions, is longitudinal in nature and differs from traditional examples of phenomena, such as experiences related to September 11th, 2001, that are more instantaneous. The phenomenological lens was selected because we wanted an in-depth understanding of the specific ways students experience a phenomenon from their perspective (Moustakas, 1994; Lester, 1999). Initially, interview transcripts were analyzed to create units of relevant meaning (Hycner, 1985). These units of relevant meaning were established and refined through peer review by the authors (Angen, 2000; Hycner, 1985). Next, units of relevant meaning were clustered for each participant resulting in a set of themes. Another pass was conducted to further cluster units of relevant meaning based on themes and patterns across respondents. Four common themes emerged across participants: ‘Future Career’, ‘Characteristics of Future Career’, ‘Future Career’s Influence on Present Action’, and ‘Past/Present Perceptions’ Influence on Future’.

Bracketing was used to limit subjectivity of the researcher during the writing of interview questions and data collection. An interpretive phenomenological approach was taken to foster student connections between future-oriented motivations and presents tasks. Interpretive phenomenology looks for deeper meaning and connections in the data that participants may not make on their own. Additionally, the interpretive approach to phenomenology relies on the use of advanced theoretical knowledge and posits that the subjectivity of the researcher cannot be removed from analysis (Lopez & Willis, 2004). Analysis of the data was conducted in its entirety by the first author in the R Qualitative Data Analysis package in R statistical software (Ronggui & Huang, 2012).

5.4 Overview of Findings

Following phenomenological tradition, the results of this paper will be presented first in an overview, followed by supporting information for the claims made in the overview. Next, implications and limitations
of this work for engineering educators will be discussed. We avoid the word conclusion as it implies a level of finality that cannot be drawn from this work (Hycner, 1985; Moustakas, 1994; Lester, 1999; Lopez & Willis, 2004).

From interview transcripts and themes developed from analysis of clustered units of relevant meaning, we are able to describe engineering student experiences with their future-oriented motivations and present tasks. Using the theoretical foundations of future time perspective, possible selves, and environmental feedback, we are able to establish connections between these constructs that can further our understanding of student learning and performance. We are able to conceptualize students’ future time perspectives as future ‘cones’ (Figure 5.1). Students establish the depth of their future cones through the use of future possible selves. All students are able to express possible selves for the future, but those who are able to define these selves with high clarity are able to project deeper into the future. The positioning of the cone base is defined by the instrumentality of tasks that students are presented with in the present. Instrumentality judgments are based on students’ perceptions of the future, and how present tasks connect to their futures. Finally, the external boundaries of the cone are generated when students evaluate the instrumentality of a task and connect this task from the present to the future. Student actions with respect to these tasks drive environmental feedback and self evaluation, leading to student refinement of the future desires. Through the course of our analyses, students demonstrated three differing experiences with their future time perspectives, possible selves, and environmental feedback. These three experiences are summarized in Figure 5.2.

The ‘Sugar Cone’ experience, visualized in Figure 5.2a, represents students who defined their future possible selves with a high level of granularity. Students in this group distinguished between minute differences in their fields of interest. Additionally, students in this group had ideal and attainable selves that were the same. The lack of difference between these selves allows students to express outcomes that may result from their participation in their future career. Being able to project outcomes of their careers assists students in defining future time perspectives further into the future than students with other cone shapes. These established future time perspectives of Sugar Cone students creates a foundation on which they evaluate present tasks. These value judgments narrow the number of tasks that are relevant to students’ desired futures. By narrowing tasks, students in the Sugar Cone group will encounter more tasks with exogenous instrumentality. While the specific tasks students are encountered with may be viewed as exogenous, higher order skills that can be gained from a task are seen as relevant to Sugar Cone students’ future goals. Higher order skills include working in teams, problem solving, critical thinking, and creativity. These higher order skills are used by students to further refine their perceptions of the future. Through acquisition of skills in the present for the
future and value judgments established through future goals, Sugar Cone students have created a feedback loop between the present and future. This feedback loop is used to further define the future and evaluate the usefulness of present tasks.

Students’ with conflicting ideal and attainable possible selves did not express their futures with the same level of clarity as those in the Sugar Cone experience. Students in the ‘Waffle Cone’ group (Figure 5.2b) expressed their careers with clarity, but did not express potential outcomes of their future careers. A lack of expression of career outcomes showed Waffle Cone students did not project their futures out as far on the time orientation axis. The conflict between these differing selves may lead students to not define their futures to the same extent as Sugar Cone students. Waffle Cone students, much like Sugar Cone students, used their future selves to determine the instrumentality of present tasks. Since these students possessed a wider range of future possibilities, more tasks in the present are viewed with endogenous instrumentality. Students with Waffle Cone experiences evaluate and apply present tasks to both possible selves in the future and further refine their future perceptions. These students have created a feedback loop between the future and the present, but they have not created an output for this loop as students with Sugar Cone experiences have.

While some students create clearly defined futures, other students have difficulty defining their futures (Figure 5.2c). While students in the ‘Cake Cone’ group did not define ideal or attainable future possible selves, they did describe future selves they wished to avoid. The ability to define what they did not want to do allows for a slight narrowing of future goals they wished to attain. Despite this narrowing, Cake Cone students had a very limited definition of the future, often stopping at graduation. Students in this group did not make connections between their future goals and present actions. The disconnect is likely due to these students’ very nebulous future goals. Students did view their actions in the present as a means for gaining all necessary skills for the infinite number of futures they might encounter. Additionally, there were limited value judgments of present tasks undertaken by Cake Cone students. Instead, these students viewed everything as useful for their future. While having a connection between the present and the future, Cake Cone students did not create the feedback loop seen in the other cone experiences.
Figure 5.2: Data reduction and analysis of transcripts revealed three different cones with future-oriented motivations and actions. Each cone represents a unique set of interactions between engineering students’ future motivations and present actions. The locations of these cones in the ‘coordinate’ system varies based on tasks encountered by students.
5.5 Detailed Description and Discussion of Findings

5.5.1 Sugar Cones: Ideal Careers that are Attainable

Figure 5.3 is a detailed depiction of the future cone or future time perspective of students in the Sugar Cone group. All of the participants with this future cone possess a positive view of the future (y-axis) as noted by their creation of future possible selves. The creation of highly detailed possible selves has led to the development of precise perceptions of the future (x-axis). Students in this group possess both endogenous and exogenous instrumentality for present tasks, and use their views of the future to limit the number of exogenous tasks. The exact placement of the present section of the future cone on the instrumentality axis (z-axis) depends on the value judgment of a specific task undertaken by a student.

Figure 5.3: Sugar Cone represents those students who have a defined future career that is both ideal and realistic. Students were able to express the desired traits of this career and what the outcomes of this career would be. Students used this highly-detailed future to narrow down relevant tasks in the present through value or instrumentality judgments. Additionally, these students were able to make direct connections from the tasks they are completing in their daily lives to their desired futures.

5.5.1.1 Depth of sugar cone students’ time orientation into the future (x-axis)

In characterizing their future time perspectives, Sugar Cone students defined their futures with a high level of clarity—deep into the future. When discussing future goals, Sugar Cone students generated detailed descriptions of their future possible selves and the steps needed to achieve these selves:
I’m going to stick with the undergraduate Bioengineering program, pursue a Master’s, and then my goal is to ultimately work for a medical device company in research and design. So, yeah, that’ll be the ultimate goal. Probably a Ph.D. also after I start working, too. (Jeremy, male bioengineer junior)

I plan to do the five year Master’s program here. And then I’m thinking about med school. I’ve taken the practice MCAT a couple of times, but I’m not sure that’s really something I want to do. But I know that I’m very interested in the imaging, bioimaging type things. I really want to work with the equipment but also people. Which is why I thought that it would be—if I was going to be a doctor I would be a radiologist. (Katherine, female bioengineer sophomore)

These students demonstrate highly developed future time perspectives that consist of a series of steps or paths to reach a distant future goal. These paths contain goals that are dependent on one another. The contingency of these goals on one another leads to increased valuing or endogenous instrumentality of a task in the present due to the implications for future goals while tasks that are not viewed as part of the contingent path will be viewed as less valuable or exogenous (Raynor, 1969).

In order to construct contingent paths, students narrow down the infinite number of possible future goals. The conceptualization of future possible selves is one way that these engineering students have narrowed their perceptions of the future. Throughout the course of Katherine’s interview she establishes that both her ideal and attainable career selves are that of a radiologist working with Doctors Without Borders. Limited differentiation between ideal and attainable career selves aids students by creating a focal point of their future time perspective. Career goals, directed by students’ possible selves, allow a student to further clarify and define the future and direct present actions. Through creation of detailed time perspectives around future possible selves, students may be more likely to determine which present tasks possess endogenous instrumentality and fall onto their contingent paths (Husman & Lens, 1999).

To further refine their future time perspectives, students create possible selves they wish to avoid alongside ideal and attainable selves. All nine of the study participants were able to name a self they wished to avoid. Unlike other participants, Sugar Cone students described avoided selves that were closely related to their ideal selves. Silas, a male bioengineering junior, expressed, “Ideally I think the anesthesiologist assistant or any sort of person in, you know, a hospital setting would be a goal. I’ve never really wanted to be like a surgeon or a doctor.” This trend is also echoed by Bonnie, a female bioengineering junior, who despite wanting to be a doctor wants to avoid becoming a surgeon. Students’ expressing possible selves to
avoid that seem in contrast to their ideal selves speaks to their highly developed future time perspectives, or depth of their time orientation axis. The high level of detail in descriptions of career aspirations allows students to distinguish minute details within professional fields that many outside observers might consider insignificant for undergraduate students. This level of distinction by students gives them the ability to have balanced possible selves (a positive hoped-for self and a negative avoided self). The establishment of balanced possible selves has been correlated to increased motivational strategies on present tasks (Markus & Nurius, 1986).

5.5.1.2 Future career characteristics

As students established the balanced details of their future perceptions, they also expressed desired outcomes for their future careers. All students possessing the Sugar Cone future perspective expressed a desire to help people as a result of their jobs:

I just want to help cure people. But I feel like if I come up with a cure, let’s say for a new drug delivery method, that will cure so many more people than I could being a doctor. Like let’s say you saved three lives a week, even if you’re really lucky, but if you find a way to deliver [therapeutic] drugs you can save thousands of people a day if you were lucky enough. (Katerina, female material science and engineering sophomore)

[I want to own my own business because] I kind of have dreams of helping people abroad too. So being able to reach out in that aspect, even providing services for people overseas or being able to send implants, or whatever is needed over there. (Jeremy, male bioengineer sophomore)

Sugar Cone students have differentiated themselves from students who possess other future cones by moving beyond the desired traits of their future careers to the results of their productivity in future careers.

In addition to the outcomes of their careers Sugar Cone students expressed the desired traits of their future careers. Silas expressed, “I don’t want to sit at a desk all day”, and Katherine noted, “I don’t think I would be happy reading about what other people have done and not be doing it myself.” While Bonnie and Katerina were the only two members of this group to not explicitly express a desire for hands-on work they both mentioned being intellectually challenged and interested in the work they were doing. Additionally, all of the students in the Sugar Cone group expressed a desire to work with others to develop or provide a solution. Bonnie provided the following description of how she views she would work with others:
I have always been a leader, Type A personality, and I think in order for me to have a good sense of fulfillment I’m going to need to be in a leadership role in my career. (Bonnie)

In this role Bonnie views herself as the lead member of the team. She goes on to elaborate about her desires to be in a position of authority, either as a department head at a hospital or an owner of a medical practice. In contrast, Silas expresses his desire to work with people as follows:

I just want to be involved with both coworkers and people that you’re working on or working with things. In research or a lab area you have a few people, but it’s mostly sort of working together for awhile, delegating a bunch of work, and then maybe coming back, and I like to work through things as a group or have that communication. (Silas)

Silas’s desire to work in a team-based environment shows that while he and Bonnie both have extremely well developed future time perspectives, they have different desired futures that have been shaped through their experiences. Student development of personal agency has led to their expression of goals of their future careers. The differences expressed in students’ future career goals may be a result of experiences that have led to the production of differing views of personal agency or differing manifestations of students’ goal setting processes (Lent, Brown, & Hackett, 2002).

5.5.1.3 Future on present

As practicing educators we are concerned with how students’ future cones influence their present actions. In this study, Sugar Cone students noted that their future perspectives gave them an intrinsic reason to work harder, focus more, and strive for learning over memorization, if the tasks were viewed as relevant (endogenous instrumentality). Students who view a task as useful, or having endogenous instrumentality by the student (e.g. the statics and dynamics of a car engine for mechanical engineers), are more likely to use strategies that are adaptive for learning (Husman & Lens, 1999). In this study, if a task was defined as having exogenous instrumentality (e.g. an engineer having to pass a leisure skills class for their degree), students reported that they were more likely to memorize and forget it, or just do what they had to so that they could proceed forward. When solving problems, students with well-defined future perceptions students stated that they were more likely to pursue and persist with endogenous tasks:

If I encounter an issue I’ll push through it a little more. If I look at it, if I’m looking at calculus, calculus is specific. I hate calculus. I’m looking at an issue like this and I have to solve a calculus problem and I run into an issue–I have no clue what to do. I’ll probably get frustrated, and come
back to it in like ten minutes. Whereas if I’m working on a problem where I know that this is something that I’m going to do, like it is directly, like I can tell, I know that I’m going to have to do this, if I do the work and get to a problem point where I’m like “Damn, I did this wrong”, I’ll work it out and do it again. I’d just say I don’t give up as easy. Put a little more effort in. (Matt, male bioengineering junior)

I definitely do judge things based on if I think this will apply later on in life. Do I need to actually understand it? Or is it just something I need to get done, in which case I just get it done and not put as much time into trying to understand it if it doesn’t click right away. So probably just like, how much effort and focus into understanding the current problem I put into and depending on if I see it applicable later on in life. (Katerina)

In making value judgments of what is and is not useful based on future goals, students with the Sugar Cone future perspective perceive which present tasks must be completed and understood to reach near future goals that enable them to obtain their future possible selves. The valuing of a task and subsequent techniques used by students begins to explain how students with similar levels of preparation may reach different levels of understanding in the same course (Husman et al., 2007; Malka & Covington, 2005).

### 5.5.1.4 Present actions for the future

Sugar Cone students create an instrumentality system that allows them to examine tasks beyond the surface details. This system allows Sugar Cone students to limit the number of tasks that are of exogenous instrumentality. Students in this group define this system using their well-defined future perceptions:

I think working in groups [is relevant to my ideal self], that would be a good example of one. Because it’s not my preferred thing to do, and I always find that I like different ways of thinking about things than other people, but basically every class forces you to do at least one group project throughout the semester. And I realize that both as an engineer and as someone in the medical field, you’re going to have to work in groups on projects and with people. (Bonnie)

In a research or lab area you have a few people but it’s mostly sort of working together for a while delegating a bunch of work and then maybe coming back, and I like to sort of work through things as a group or have that communication. (Silas)
Through defining their own value system, students may overcome the traditional values outlined by the dominant cultures in the field of engineering. This may explain why some people with non-traditional backgrounds flourish while others take their skills to other domains in the university system. We support this claim with Katerina, who despite being a high-performing student in bioengineering, switched majors to materials science and engineering due to a perceived ability to make a greater impact on the world. Additionally, students in engineering who value social skills, such as group work, go against perceived cultural norms within engineering that place value on the technical over the social (Riley, 2008; Cech & Waidzunas, 2011).

In addition to teaming skills, Sugar Cone students are using their problem solving tasks to develop skills for their future career:

I think it’s just being able to analyze a problem which is, when you’re working or when you’re doing any kind of job, you’ll run into problems, and basically the same steps apply for when you run into those problems at work because you have to analyze the problem. So I feel like the basic process of solving an engineering problem applies to [my desired future] work. (Jeremy)

The broad spectrum of things given to you and solving the problem with that information yourself and applying the right techniques to it—that’s something you don’t necessarily get in all types of majors. Obviously there’s knowledge to know and some people are good at memorizing, but actually working through a task and problem solving, I think is something that you best learn within engineering classes, and that’s something that is involved in most careers. (Silas)

Sugar Cone students developing skills to prepare themselves for future tasks and goals create a feedback loop wherein students refine their perceptions of the future and use these refined perceptions to determine the value of present tasks. By accomplishing tasks in the present, students are able to generate more defined future cones. Connections between future goals and present actions through perceived instrumentality allow students to leverage dispositional and situational traits, which has been shown lead to increased performance (Husman et al., 2007; Malka & Covington, 2005).

5.5.2 Waffle Cone: Ideal and Attainable Career Discrepancies

While Sugar Cone students are able to define their futures with a high level of detail deep into the future, other students did not project with the same level of clarity. Waffle Cone students who have future careers that are well-defined did not express future goals beyond that of their first career after graduation.
Stefan, a male mechanical engineering junior, described his future through discussion of potential future employers:

I’m co-oping at [Major Automotive Firm] and it’s gone really well so far, so I feel like there’s a good chance I could go in with them. And there’s a company in California that I’m looking at that does airplanes, so if I heard back from one of them and if it was a good opportunity I’d probably take that. (Stefan)

As the conversation progressed, Stefan mentioned that he would ideally work for Aviation Firm, but thinks that he can attain a position at Major Automotive Firm. Stefan describes his avoided self as someone working in an ice cream shop. The conceptualization of future possible selves matches that of Sugar Cone students, in that Stefan has created ideal, attainable, and avoided selves. While discussing careers he wishes to avoid, Stefan also notes:

[I don’t want to be] in a place that’s really corporate like [Major Automotive Firm]. Like, you can move up and it’s a great job obviously right out of college, but I can only move up so much. And so that’s one thing that I don’t want to do forever and just being in a really corporate business. (Stefan)

Through this statement, Stefan has distinguished himself from his peers in the Sugar Cone group. In a Waffle Cone future time perspective, students possess ideal and attainable selves that differ from one another. Sugar Cone students have ideal and attainable selves that are closely aligned. Additionally, Stefan’s comments indicate that part of his attainable self is also part of his avoided self. This discrepancy between selves may limit the ability of those with Waffle Cone future time perspectives to project into the future or further down the time orientation axis. This came to light through Stefan’s comments in that he did not express a desired outcome of his future career (e.g. building a better car or plane) and that he was not able to project beyond ten years into the future:

If I was at [Major Automotive Firm] or maybe another company, I’ll probably stay there five or ten years. Ten years [in the future] is pretty hard to describe. (Stefan)

While ten years is not the near future, this future perception is closer to the present than that of Sugar Cone, students who projected twenty to thirty years into the future. This decreased depth into the future by the Waffle Cone student may lead to decreased achievement-based motivation for present tasks (Husman & Lens,
This altering of motivation on present-based tasks may lead to decreased performance on academic activities.

Similar to Sugar Cones, Waffle Cone future time perspectives establish connections between the future and the present. These connections are again directed by students’ instrumentality judgments.

Statics and Dynamics, I really try to learn everything. I really enjoy the material, and I thought it was great. So things that are obviously related to my major—I probably shouldn’t think like this—but classes like, that I really want to learn the material. And then there are classes like physics. It’s still related but I just memorize a lot of stuff. Probably a week after the test I couldn’t tell you what was on it. (Stefan)

This idea was reinforced by Stefan throughout the course of the interview with comments like, “I guess, if the class applies to my future goals, that’s when I will learn it”. This connection from future goals to present tasks mirrors the perceived instrumentality connections made by Sugar Cone students and displays elements of connectedness outlined in the future time perspective literature (Husman et al., 2007).

Waffle Cone time perspectives created connections from skills being developed in the present for refinement of the future.

I really like testing things and seeing the results. I guess that sounds kind of vague, but I mean that can be in industry or research. So I guess my career goal is that I do end up with something hands on in automotive or aviation. (Stefan)

In order to end up working in testing and analysis, Stefan feels that he needs to be able to think critically and understand the background of the system he is working on.

It’s funny because once again going to my co-op, nobody’s using anything from classes that I have learned. But [my classes] are all relevant because you have to be able to think critically.

And how I think about things has definitely changed while I have been in engineering.

Similar to Sugar Cone time perspective, the Waffle Cone student works to limit which tasks are viewed with exogenous instrumentality. While Stefan is taking a number of engineering courses, he does not feel that the specific information learned in his courses is relevant to his future. Rather, the cognitive and metacognitive processes he is learning are relevant. The increased instrumentality of tasks through identification of higher level skills may lead both Sugar and Waffle Cone students to be more self-regulated learners (P. R. Pintrich, 1999).
The Waffle Cone future perspective is summarized in Figure 5.4. This perspective is able to establish the feedback loop between the present in the future to connect their actions to their goals. In this perspective, outcomes of work in a future career are not discussed, displaying limited depth of the time perspective. The limitation in depth may be due to the conflict between ideal and attainable goals, as the dreams of a student may not match their reality.

Figure 5.4: Waffle Cone: This cone represents those students who had a defined ideal future career and realistic career that were not similar. Students in this group were able to express desired traits of their future careers, but they did not express what outcomes they hoped to get from their future career.

5.5.3 Cake Cone: Lack of a Future and Lack of Dispositional Components

Students with Sugar or Waffle Cone time perspectives were able to define their futures with a relatively high level of clarity. In contrast, students who possess a Cake Cone time perspective provide limited definition of their futures and have difficulty connecting their futures to their present actions. Additionally, students in this group are not using their futures to create value judgments of what tasks are or are not important. The limited valuation of tasks leads students in this group to view all tasks as relevant to helping them define their future.

Cake Cone students define their future in two ways. First, these students are able to define careers that they do not want to do:
I’m not really sure what I want to do with engineering yet. Sometimes it seems to focus on automotive a lot. I don’t find that particularly interesting. (Caroline, female mechanical engineering sophomore)

I don’t want to be a garbage man or sort of a standard factory worker. I don’t want to necessarily just work at a desk all day. I definitely don’t want to be an electrical engineer after this last class. (Damon, male mechanical engineering sophomore)

In defining the specific jobs these students wished to avoid, they are also able to define the characteristics of jobs they wish to have:

I wouldn’t want to be stuck doing just one tiny part. I’m a big picture person so it would be really fun to be involved in all aspects of something. (Caroline)

Honestly [I want] to be successful. Just live up to what my parents have accomplished at least. I’d say I’m half and half between monetary success and I guess happiness with what I am doing. (Damon)

These students’ descriptions of their futures are lacking the depth on the time orientation axis seen in both previous cone types, the balance of future possible selves seen in the Sugar Cone, and the conflicting possible selves of the Waffle Cone. Cake Cone students did not express an ideal future they wished to have. The only future goal expressed by these students was to reach graduation in their currently declared major. This lack of depth into the future requires students to rely purely on the intrinsic enjoyment of learning, which may not be present in the classes these students are required to take (Kauffman & Husman, 2004). The reliance on only one source of motivation may lead these students to adapt practices that are not conducive to the levels of learning desired by educators (P. R. Pintrich, 1999).

When discussing ways in which Cake Cone students viewed their future interacting with the present students often noted that there were limited or no connections from the future to the present.

I don’t think [my future goals] have really too much of an effect. At least none that really stick out. (Damon)

Despite not connecting the future to the present, Cake Cone students did see a connection between present tasks and their possible futures:

I don’t really know what my future goals are yet, so kind of whatever experiences I can get now will hopefully help me in the future. (Caroline)
Using their current experiences to narrow down their possible futures demonstrates that while having an undefined view of the future, these students do view time positively, and feel that their current actions will help them in the future. This connection between the present and the future may serve as a starting point from which students can begin to construct more detailed time perspectives. In order to develop a more detailed time perspective, Cake Cone students will have to leverage their intrinsic motivation for present tasks to create a future identity that can be used for goal setting (Husman & Lens, 1999; Raynor, 1969; Kauffman & Husman, 2004; Lent et al., 2002). Figure 5.5 summarizes the limited connections made between the future and present for Cake Cone students.

![Figure 5.5: Cake Cone](image)

Figure 5.5: Cake Cone: This representation of student future time perspectives indicates students who could not express a desired future career. Students in this group could only express a limited number of jobs that they did not want to do. Students in this group expressed a desire to keep their options open and not limit themselves.

### 5.6 Implications

Our goal in establishing these future cones is not to create a valued-based classification system that identifies one cone is superior to another, but rather to understand the different student experiences in terms of connecting future-oriented motivations and present actions. Students have demonstrated three different experiences with this phenomena that range from highly defined perceptions of the future with clear
connections of the present to ill-defined perceptions of the future where students view their present situations as limitless. These three experiences provide an insight into understanding how students with similar levels of preparation may have different learning outcomes in similar courses.

For a course level context, discussions of students’ futures should be more than a one-off seminar or lecture. Students in this population discussed evaluating a number of different present tasks based on their future-oriented motivations. This continual evaluation by students indicates that discussions of careers and tasks performed by engineers should be revisited throughout the course of students’ experiences while working toward an engineering degree. All students in this study had a positive view of the future. Providing students with a future-oriented engineering education may help them better shape their future time perspectives. While we have shown that students have a range of future time perspectives all students discussed the positive influence of the present on the future. As such, discussions of the future may be able to assist students with the cones presented in this work develop increased future-oriented and task-specific motivations (Kauffman & Husman, 2004).

Many of the students in this population have future goals that go beyond the boundaries of engineering. Engineering educators may view the migration of these students away from engineering as a loss (Ayrea, Millsa, & Gillb, 2013). Based on students’ discussions of their future time perspectives we propose that this exodus is a gain for society. Students often discussed the problem solving skills, critical thinking skills, and general knowledge they are gaining from their engineering courses, and how they can apply these skills to an outside field. The migration of these students to fields not traditionally accessed by engineers may help advance the understanding of engineering and its role in benefiting society.

Finally, this work extends the theoretical understanding of future time perspective as it relates to engineering students. Creating an understanding of future time perspective for engineers has been outlined as a need for furthering the future-oriented motivation work (Husman et al., 2007). We have also established an understanding of how students’ dispositional (or stable) future-oriented traits interact with situational motivations. Specifically, we are able to demonstrate that students are creating a feedback loop between present tasks and future goals. This idea allows motivational theorists to better understand how and why situational and dispositional traits are correlated, and what is driving these correlations for engineering students (Kauffman & Husman, 2004; Husman & Shell, 2008).
5.7 Issues and Future Work

The phenomena of connecting students’ future oriented motivations to present tasks is one that is longitudinal in nature. For this work, we have only taken a cross-sectional view of students’ interaction with this phenomena and cannot speak to the ways in which students’ future time perspectives or cones developed; we can only speak to the descriptions of student cones in the moment. In her interview, Katerina described a process by which she worked to develop her perceptions of the future:

Every day I kind of think of something else that will be cool or not cool and I try to fit that into what I think I want to do in the future, and I guess eventually it keeps evolving into a different future based on stuff that I add to it. And how concrete any of that is depends on how well all these pieces fit together and hopefully they actually end up being some form of research that I want to do. (Katerina)

This description outlines the need for future work exploring the longitudinal nature of future cone development and the ways in which these cones drive student action. Additionally, this study provides a rich description of students at a single institution in a limited range of engineering majors. As such we may not have captured the full range of student experiences with this phenomena. Due to students possessing similar majors we cannot evaluate how the disciplinary cultures in engineering programs influence the development and maintenance of students’ future time perspectives. In order to study the influence of departmental cultures on students’ time perspectives, the population of this study must be expanded and the conversational prompts used in the interviews must change to reflect this new research question. Finally, the results presented in this work serve as a foundation on which to begin implementation of classroom innovations and pedagogical reform. Implementation of classroom innovations requires careful study and attention.

5.8 Summary of Findings

This study examined nine engineering students’ experiences with their future oriented motivations and actions taken toward present tasks. The goal of this work was to better understand how student future-oriented and task-oriented motivations interact and influence actions taken in the present. Future Time Perspective and possible selves were used as theoretical lenses to examine this goal. Student discussions displayed three different ways that students interact with their future-oriented and task-based motivations. Sugar Cone students displayed highly-defined futures that interacted strongly with present actions, which were then
used to define the future. Waffle Cone time perspectives also contain highly-developed perceptions of the future, but display conflict between ideal and attainable selves which may limit the depth into the future that students can define their careers. Cake Cone students lack a clearly defined future, and do not create connections between the future and present. These results demonstrate a range of future time perspectives that students may have in an engineering classroom. This work supports and extends the theoretical understanding of future time perspective literature through understanding the ways in which engineering students experience this phenomena.
Chapter 6

What is the Value of an Engineering Problem?: Motivational Drivers that Influence Engineering Students’ Perceptions of Engineering Problem Solving.

6.1 Introduction

Recent reports have asked engineering educators to rise above the gathering storm (Committee on Prospering in the Global Economy of the 21st Century: An Agenda for American Science and Technology; Committee on Science, Engineering, of Medicine (IOM); Policy, & of Sciences; National Academy of Engineering, 2007; President’s Council of Advisors on Science and Technology & Presidents Council of Advisors on Science and Technology, 2012), work to warm a chilly climate (Seymour & Hewitt, 1997), and incorporate new individuals into the fields of engineering to address a series of grand challenges (of Engineering, 2012). These calls for improvement in engineering education have lead engineering educators down a number of paths to figure out how to best recruit (Jesiek, Newswander, & Borrego, 2009), retain (Ohland et al.,
2008), and prepare students for a future of engineering (Hutchison et al., 2006). In seeking to understand how students are prepared to approach the grand challenges of engineering researchers have sought to understand how students solve engineering problems across a range of contexts (McCracken & Newstetter, 2001; Cooper & Sandi-Urena, 2009; Benson et al., 2011). In trying to meet the demands of a technologically literate workforce, researchers have sought to understand student motivation as it is a driver for choice, persistence, and performance (Benson et al., 2013; Matusovich et al., 2010; Koh et al., 2010). These two fields of study, motivation and problem solving, have emerged from traditional psychology paradigms, and few have addressed how they may influence one another for engineering students. In this work we seek creation of a bridge between affective and cognitive domains through the study of student motivation and problem solving.

Student perceptions of student motivation are often used to understand student performance, choice, and action. Student motivation has been shown to influence persistence and performance for college level engineering students (Benson et al., 2013; Jones et al., 2010). Academic performance has also been shown to be influenced by students’ self-efficacy in introductory engineering environments (Hutchison et al., 2006). These indications of the effect of student motivation on student action in the engineering classroom have focused predominately on engineering goals in the present and have not take into account the importance of students’ long-term goals with respect to their actions, performance, and learning. Motivation related to long-term goals has been shown to increase the values of present tasks, persistence on tasks, and learning in and out of engineering education environments (Husman & Lens, 1999). The effects of students’ long-term goals in engineering has not been as thoroughly studied compared to other aspects of student motivation.

A commonly used framework in engineering education is that of a novice compared to an expert (Baillie, Ko, Newstetter, & Radcliffe, 2011; Borrego & Newswander, 2008; Steif, Lobue, Kara, & Fay, 2010; Chi et al., 1981). This framework is often used to understand what students are not doing but need to be doing to be considered an expert in a field. This framework rests on the assumption that students will eventually become experts. It has been shown that the time required to become an expert in nearly anything is 10,000 hours (Ericsson et al., 2006). Students are often not focused on a particular task or set of skills for this period of time during their educational experiences. In order to better understand student experiences with problem solving and what engineering problems are, we must understand how our students define engineering problems based on their current progress to becoming experts.

In order to better understand students experiences with motivation toward long-term goals (e.g. career aspirations) and short-term tasks, such as engineering problem solving, we set out to answer the following research questions:
1. How do students’ motivations driven by long-term goals correspond to their definitions of engineering problems?

2. How do students’ motivational profiles correspond to the things they wish to gain from solving an engineering problem?

3. How do student motivational profiles correspond to student perceived tasks undertaken when solving unfamiliar or challenging problems?

### 6.2 Theoretical Frameworks

Our work utilizes the theoretical foundation of motivated action theory (DeShon & Gillespie, 2005). This theory assumes that all student action is driven by a series of complex motivational drivers. These drivers range from stable traits with their foundation in self determination theory (Deci & Ryan, 1991) to unstable characteristics driven by contextual clues of a situation. One framework that explains situational motivation is self-efficacy, which examines if students think they can successfully perform certain actions in a given scenario (Bandura, 1986). Motivated action theory suggests that these different levels of motivation are all interconnected to drive action. While motivated action theory rests its theoretical construction around goal orientation literature (Dweck & Leggett, 1988), it does not provide a means of operationalizing the framework to understand how interconnected levels of student motivation may drive action.

To understand how student action is driven by interconnected levels of student motivation with respect to time, we use two frameworks that consider the time-scales of student goals. Future time perspective describes how students’ future oriented quasi-stable goals create connections to student action in the present (Husman & Lens, 1999). These connections are driven through students’ value judgments of a current task’s usefulness for a desired future. Future time perspective consists of three main components: students have either a positive or negative view of time’s ability to make things better; students focus on time with an orientation along a continuum from the past to the present; and based on students’ time orientations, their perceptions of the usefulness of tasks can range from endogenous to exogenous instrumentality. A task that has endogenous instrumentality is one that students view as directly useful to obtaining a future goal (e.g. completing a senior design project creating a medical device for a bioengineering degree), while a task that is of exogenous instrumentality is one that a student must complete but they do not view as relevant to a future goal (e.g. completing a leisure skills course as a requirement within an engineering degree program). This
framework has been used to understand student persistence in engineering (Benson et al., 2013) but has yet to be applied to students completion of short-term tasks in their engineering classes, such as problem solving.

Possible selves serves as an additional theoretical foundation for the understanding of how students’ future goals may influence action on short-term tasks. Possible selves looks at who students want to become, think they can become, and want to avoid becoming (Markus & Nurius, 1986). This work has shown that students with balanced possible selves (having ideal and avoided possible selves) have had increased motivations on tasks in the present (Husman & Lens, 1999; Oyserman et al., 2006). Additionally, students’ with balanced possible selves have been shown to lead to increased persistence and knowledge seeking for college enrollment of students coming from disadvantaged backgrounds (Pizzolato, 2007). Similar to future time perspective, possible selves has had limited to no application in the study of the role of long-term goals on problem solving in engineering.

6.3 Methods and Participants

Self-selected participants were solicited from a population of 153 second year mechanical and bio-engineering students who completed a survey in the Fall of 2012. In class announcements and invitation emails occurred for a period of two weeks in sophomore-level mechanical engineering and bioengineering courses in Spring 2013. An additional recruitment period occurred in Fall 2013 in a junior level bioengineering course. The same techniques were used in this second round of recruitment. Snowball sampling, in which participants recruited peers to participate, was used to recruit additional study participants. Participants completed a semi-structured interview related to future-oriented motivations, task-oriented motivations, and perceptions of engineering problems. Interviews ranged from 39 to 95 minutes in length. Student responses to the interview questions were used to direct detailed discussions during the interview process. Additional questions by the research team were used where appropriate for clarification and depth.

A phenomenological lens was used for the collection and analysis of data. The power of phenomenology lies in the fact that it allows for the rich understanding of participants motivations and actions (Lester, 1999). For this study, the phenomenon of interest was how students’ motivations related to long-term goals and short-term tasks influenced their perceptions of engineering problems. Prior work classified and described in detail differences in students’ engineering future time perspectives, or future cones. This prior work indicated the presence of three motivation profiles or what the research team termed “cones”; Sugar Cones are cones with highly defined futures and clear descriptions of the influence of present tasks and future
motivations; Waffle Cones show well defined futures that are in conflict with one another leading to a lack of career outcomes expressed but still show a feedback loop between future-oriented motivations and task-specific motivations; and Cake Cones show little definition of the future with no descriptions of a feedback loop between the present and future. Descriptive information of the student population of this study can be found in Table 6.1. Race/ethnicity status are not reported in order to maintain anonymity of the participants.

Table 6.1: Participant descriptive information including future time perspective cone, year, and major.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Cone</th>
<th>Year</th>
<th>Major</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damon</td>
<td>Cake</td>
<td>Sophomore</td>
<td>Mechanical Engineer</td>
</tr>
<tr>
<td>Caroline</td>
<td>Cake</td>
<td>Sophomore</td>
<td>Mechanical Engineer</td>
</tr>
<tr>
<td>Bonnie</td>
<td>Sugar</td>
<td>Junior</td>
<td>Bioengineer</td>
</tr>
<tr>
<td>Jeremy</td>
<td>Sugar</td>
<td>Junior</td>
<td>Bioengineer</td>
</tr>
<tr>
<td>Silas</td>
<td>Sugar</td>
<td>Junior</td>
<td>Bioengineer</td>
</tr>
<tr>
<td>Katerina</td>
<td>Sugar</td>
<td>Sophomore</td>
<td>Materials Science and Engineering</td>
</tr>
<tr>
<td>Katherine</td>
<td>Sugar</td>
<td>Sophomore</td>
<td>Bioengineer</td>
</tr>
<tr>
<td>Matt</td>
<td>Sugar</td>
<td>Junior</td>
<td>Bioengineer</td>
</tr>
<tr>
<td>Stefan</td>
<td>Waffle</td>
<td>Sophomore</td>
<td>Mechanical Engineer</td>
</tr>
</tbody>
</table>

In order to understand students’ perceptions of engineering problems, participants were asked to define an engineering problem across multiple contexts including a general definition, a definition of engineering problems in their course work, and an engineering problem that would be beneficial to them. Additionally, participants were asked what value they saw in solving engineering problems. Connections between student motivation cones and these views of engineering problem solving were made by the lead researcher through the use of interpretive phenomenology (Hycner, 1985; Lopez & Willis, 2004). An interpretive lens was used in order to establish connections between different aspects of student interviews that they may not be able to make on their own (Lopez & Willis, 2004). Coding of interview data occurred in R Qualitative Data Analysis software (Ronggui & Huang, 2012). Interviews were first coded by participant, to create units of relevant meaning. These units of relevant meaning were then clustered together by themes. These themes were then further reduced through cross-participant comparison.

### 6.4 Overview of Findings

Analysis of interviews revealed that specificity of future goals drives student perceptions of engineering problems. Students with Sugar Cone future time perspectives had one of two perceptions of what an engineering problem is. Those with the highest level of clarity, define engineering problems based on the
steps needed to solve an engineering problem (i.e. finding knowns, unknowns, filtering out information, solving for equations, and determining an answer). Sugar Cone students with less expressed clarity of their future time perspectives described an engineering problem as something that exists to improve technology and/or quality of life. The Waffle Cone perspective described an engineering problem as any problem one may encounter in any context, but tends to be for improving technology. While this description may seem similar to Sugar Cone descriptions of improving technology, with the Waffle Cone student, there is the additional perspective that everything is an engineering problem. Cake Cone students describe an engineering problem as anything. The lack of detailed descriptions of engineering problems by Cake Cone students mirrors their limited descriptions of their engineering future.

These descriptions of engineering problems are mirrored when these students discuss problems that they view as beneficial for them. Sugar Cone students who described engineering problems as a series of steps wanted well-defined problems with a limited number of or types of paths to a solution. Those Sugar Cone students who described engineering problems as a way to improve technology and/or quality of life wanted open-ended problems that allow for multiple solutions in their engineering experiences. The Waffle Cone time perspective mirrors the views of the latter group of Sugar Cone students by describing a problem with limited instructions and statement of the problem as a beneficial engineering problem. Matching their open-ended description of an engineering problem, Cake Cone students thought that open-ended problems with multiple answers would be beneficial in their engineering careers.

While students expressed the values gained from solving engineering problems across multiple contexts, these expressions did not vary greatly across cone types. Students felt that the value of solving engineering problems came from the creation of technology and/or something for quality of life improvements. Other perceptions of the value of engineering problems included the enjoyment of solving difficult problems and gaining skills for future employment. The idea of gaining skills is mirrored when asking students about what they hope to get when solving problems for class. Often students first expressed that they were solving problems for a grade, but students also expressed that they gained skills such as critical thinking, independent ability, and evaluative skills. Student discussion of these skills often occurred without additional prompting by the research team.

Finally, when asked what they would do when solving an unfamiliar or challenging problem, student responses appear independent of cone type. All of the students mentioned breaking the problem into parts, finding the unknown, and figuring out a path to the solution. Seeing this discussion of steps taken to solve an engineering problem displayed across students in a consistent pattern may indicate that students’ perceptions
of what they think should do during problem solving is affected more by training than motivation.

6.5 Detailed Description and Discussion of Findings

6.5.0.1 Student Descriptions of Engineering Problems Across Contexts

While students described what an engineering problem was across multiple contexts (generally, in their courses, and an engineering problem they thought was beneficial), their contextual descriptions often supported or elaborated on the initial descriptions of an engineering problem in a general context. As such, the following detailed results and discussions of students of student descriptions are divided based on the themes from analysis and not based on the contexts they were asked to discuss.

6.5.0.2 Specific Perceptions of the Future and Specific Definitions of Engineering Problems

When asked to define an engineering problem Sugar Cone students generated two different definitions. The students who defined their future perceptions further into the future described an engineering problem as a series of steps leading to a solution:

An engineering problem to me, first of all it’s hard, but it’s just something that requires you to use your basic knowledge to be able to solve a pretty complex mathematical problem. It’s just being able to look at a problem and being able to pick out what you know, what you don’t know, and then use your knowledge of or understanding of the problem to be able to solve it and get an answer. (Jeremy)

I think it’s one where you’re going to have all sorts of different information, from different sources. Those sources could be your client if you’re an engineering firm, or it could just be the previous literature. So you’re going to have to take everything that’s relevant to the problem, filter through it, get rid of the extraneous information. Then you’re going to have to apply the fundamentals to it. Then you’re going to have to engineer a solution to fix that problem. (Bonnie)

The engineering problem just gives you the information with an end goal and doesn’t necessarily give you a step by step approach. Engineering will just lay it out in paragraphs of information and then tell you one thing and have you have to pick and choose what you need to figure out the way to solve it and reach the answer. (Silas)
These linear descriptions of problem solving mirror the steps that these students feel they must accomplish in order to reach their future goals. The three students’ descriptions outlined here demonstrate the steps for problem solving that are emphasized throughout an engineering degree. The conceptualization that engineering problems can be solved through step-wise processes may have been internalized by these students in order to obtain their desired success levels in engineering. When asked to discuss problems these students viewed as beneficial, the discussion of engineering problem solving as a linear process continued:

I think well-defined is good because it’s easier to find a starting place. And I guess that in itself is better communication because if you’re going to work with someone and you don’t actually know what they want then that is a problem. (Bonnie)

What’s beneficial to me would be something that relates to my field. I don’t like the possibility of multiple answers. And the problem should be well-defined. To be able to look at it, if you read through it carefully you should be able to pick out what you need to know. So I don’t think they should be written to trick people or whatever, but I know a lot of them are like that, where they give you multiple variables and then you have to decide which one you want to use. (Jeremy)

Bonnie and Jeremy express the desire for well defined problems so they can actually work through them and apply information that they know. The desire to apply information and knowledge to reach a solution may be related to performance orientations of these students which has been strongly tied to one’s future time perspective or cone (Husman et al., 1996; Kaplan & Maehr, 2006). Additionally, these students also mentioned that beneficial problems would reside in a relevant context for them. These students, all bioengineering majors, considered a relevant context to be bioengineering.

Despite the similarities in terms of problem definition, Silas does differ from Jeremy and Bonnie when describing a beneficial engineering problem:

I’d definitely prefer more open-ended questions that allow a person to answer the question and elaborate why they chose their answer. Because not every time there is a clear-cut solution to a problem. It’s something that you solve and proves the problem but you have to possibly pick and choose why one is maybe still better than the other and being able to justify that now is something that’ll probably show up more in the future in an engineering career. (Silas)

Silas views a beneficial problem as one that is open-ended and gives him multiple paths to follow. When examining Silas’s discussion of engineering problems, he did not explicitly mention all of the steps considered
in a problem solving process, but instead mentioned more general ideas of how to work through an engineering problem. This variation in definition from Jeremy and Bonnie, while subtle, only becomes salient when the desired problem styles of these students is examined. This desire for open-ended problems may represent possession of a more mastery based goal orientation than Bonnie and Jeremy (Husman et al., 1996; Kaplan & Maehr, 2006).

When students were asked about engineering problems in their courses, they noted that the problems matched their initial definitions, but expanded on their definitions by stating that these problems were now situated in a particular context:

Thermodynamics definitely has a lot of engineering applications to it. And then even in Biomechanics we use, for our statics problems and things like that we use some engineering principles there. (Jeremy)

Students’ descriptions of course level engineering problems may be driven by their cones, but they also may be driven by the types of problems that they are presented with; they are not creating unique definitions. Additionally, students had taken few major specific courses at the time of their interviews and may have only seen problems that were similar to previous experiences with only slightly changed context.

In contrast to their Sugar Cone peers, Katerina, Matt, and Katherine defined an engineering problem as a way to improve existing technologies:

An engineering problem would be an issue in the world in which there’s either a solution present. I feel like there are problems that have engineering solutions which makes it an engineering problem, but really just anything that requires a not natural solution, I suppose. (Matt)

I think it’s mostly just technology and just continue to improve the technologies that we have and then make new ones that are going to keep getting better and keep surpassing what we already have. (Katherine)

It’s finding a new approach to solve a problem that may already have an answer but just not the best one. It’s modifying something so that I guess it works better and easier for the future. (Katerina)

These students view engineering problems not as a series of steps but rather as a means to an end of improved technologies. In order to develop these new technologies, these students feel that they need problems that allow them to explore the possibilities of improving technologies:
With instrument design it’s always good to not have a specific thing you want in mind. Obviously you want it to serve a purpose so you have that purpose, but then the way that you design it can be very varied from person to person. And I think that’s a good thing because then you can have all kinds of different ideas, and figure out which one is best for the purpose you want to accomplish with the machine. (Katherine)

I enjoy the ones where you’re given two variables and you’ve just got to figure it out. You’re given something and you can easily find one part of it, but what you’re supposed to do, you’ve got to take that and then reapply it to the problem and find a different value that isn’t obvious. But it takes a little more, a little further looking into it, to realize that you can calculate a couple other variables as well. (Matt)

I like being able to approach a problem from multiple ways if possible because I feel like even if one of those ways is wrong for that problem, it might lead you to like an idea or down a path to a different solution for something else. If you have one path that you’re approaching something over like you might get stuck and think that you’re done and there’s no answer. And if you have multiple paths of trying it out, you might find something that actually works. (Katerina)

The matching of student definitions of problems to the problems that they view as beneficial may indicate that students futures are driving their perceptions of both the field and the problems that would be useful to their role in their desire fields. These students with a technology and/or quality of life focus for engineering problems shared similar views to the other Sugar Cone students in that their general definition of an engineering only changed through the addition of context for class based problems.

6.5.0.3 A Future Perception of Multiple Paths and Mixed Definitions of Engineering Problems

One student, Stefan, had a Waffle Cone future time perspective. This cone consists of having ideal and attainable possible selves that he views as distinct from one another. In addition to having mixed views of his future careers, Stefan also has mixed views of what an engineering problem is:

As an undergrad student, I’d say it’s pretty much something out of a textbook that you work for a couple hours pretty much and hate for a little while and then are really happy once you get it. It’s just making things work. I guess [general education problems] are basically the same. Sometimes you have to look at it and see how you’re going to do it, but in terms of solving a problem, no.
Stefan’s definition of an engineering problem ranges from anything (bridging across all contexts) to the idea of making things work. The idea of making things work is similar to Sugar Cone students who discussed wanting to improve technologies. Putting something back together or making an idea work is essential to technological advancement. However, the idea that an engineering problem can be anything makes Stefan unique from those students with Sugar Cone perspectives. The idea that an engineering problem is anything may come from the fact that Stefan is working with multiple career paths in mind, and feels that he must keep his options open in order to make himself as valuable as possible in each potential career field.

In order to gain skills for his future career Stefan sees value not in solving step by step problems, but instead being given a problem and the space to solve the problem in his own way:

> Taking a problem and not giving somebody a set of instructions to do it, sometimes that means pulling formulas or pulling concepts from other problems and applying it to that one. I think it would be saying this is what’s wrong and not saying do this to fix it. The objective has be clear. [I] can’t go into a test if it doesn’t tell me what to find. I can’t find anything. (Stefan)

While asking for a level of clarity in problem setup, Stefan does not desire a prescriptive problem solving process. His desire to work in the automotive and aeronautical industries may be driving his desire to see these types of problems. At a different point in the interview Stefan describes the enjoyment he gets from solving problems on his own, and being able to contribute to the greater body of knowledge for industry and academia. Through his experiences with companies that hire in his desired future careers, Stefan has encountered these open-ended style problems and sees being able to work with these problems as beneficial.

### 6.5.0.4 Limited Perceptions of the Future and Limited Definition of Engineering Problems

Cake Cone students view the future as a space of infinite opportunities. When describing an engineering problem the students with these cones presented definitions that were similar to their perceptions of the future:

> Anything [is an engineering problem]. To me the definition of engineering is problem solving so it can pretty much be anything. (Caroline)

> Essentially any problem can be looked at in an engineering way. It’s more about how you go solving the problem instead of defining what the problem is. (Damon)

The open-ended nature of Caroline and Damon’s definition of an engineering problem reflects their view of how open-ended the field of engineering is to them. As both of these students were prompted about the
context of engineering problems their definitions were refined slightly to reflect their interest in mechanical engineering. These students talked about the importance of context and being able to fix something that is broken. This slight narrowing continues to reflect students future cones that narrow slightly due to an interest in engineering, specifically mechanical engineering.

When asked to define a problem that would be beneficial to them these students expressed a desire for open-ended problems that allowed for exploration of the topic.

Since I’m doing mechanical engineering and not some other kind of engineering, the problem that would be beneficial to me would be something that’s broken, something that you can physically fix or something that needs to work right, not something that you can just say the material is wrong. For me I would like it to be more open-ended and have different options I could try. I don’t really like when you have to follow specific steps to get the precise answer. (Caroline)

[A beneficial problem let’s me] go off and explore. It lets you be creative. Engineering is kind of about being creative, ah, finding solutions. No actual real world problem has one exact solution, it’s broad. (Damon)

6.5.0.5 Student Problem Definitions and Perceived Instrumentality

Asking students to define a problem that is beneficial to them asks them to create a value judgment. One such way students may be making this value judgment is through examination of the instrumentality of the problem solving task, which can be either endogenous or exogenous instrumentality. By asking students about a problem they view as beneficial we are then asking them to define a problem that they perceive to have endogenous instrumentality. It has been shown in previous work that perceived instrumentality relates to students perceptions of the future (Husman & Lens, 1999) or their cones. The connectedness of student definitions of engineering problems and their cones supports the ideas established in the literature showing that present tasks are connected to future goals through value or instrumentality judgments.

The discussions of students’ general definitions of engineering problems matching both their cones and beneficial definitions brings to light how future goals may shape students’ understanding and learning of engineering content. All of these students have a perception of the field of engineering as a whole that is directly relevant to their future goals. This connection between a general field perception may speak to a student’s evaluation of the usefulness of an entire field in allowing them to reach their goals. The continued evaluation of a field based on its usefulness to students may lead to differing cognitive manifestations in the
field over time. Additionally, this valuation system based on students’ future goals may lead to differences in cognitive gain through the course of a semester. A student who feels challenged by the introduction of open-ended problems in an upper-level engineering course may be resistant to this new task not just because it threatens the student’s perceptions of performance but also because the student does not see the value of tasks with multiple solution paths. Students who have a future that includes the exploration of open-ended problems to try and improve the world may struggle in introductory courses that focus on well-defined exercises that have already been addressed through the history of the field.

As students’ descriptions of engineering problems transitioned from general definitions to course level definitions to beneficial problem definitions, these students’ discussions of problem contexts shifted to focus on a specific field of study. The problems given to students in their courses with their engineering major may have the same underlying features as problems in other engineering or science fields. Although students may not be able to see the value of engineering theory, they are better able to appreciate that theory when applied to a specific context of interest. This idea of context driving instrumentality judgments may explain why some students begin to perform at a higher level upon entering major specific courses.

6.5.1 Perceived Value of Engineering Problems Across Context

Student perceive the value of an engineering problem as the place to make better products and gain skills. Students made mention of both products and skills without an apparent connection to their cones. Students saw the value of engineering problems in general as the improvement of life through the creation of new products:

Because there’s problems to be solved. There’s always ways to improve for life and longevity of products ant I think people try to find any type of problem they see within our life and fix it. (Silas)

Typically an engineering problem has a very beneficial solution, whether it’s a shorter time needed to do something, whether it’s shortened distance. So many of these problems are beneficial [when solved]. (Matt)

In contrast to the definitions of engineering problems, the value of engineering problems changed when the context of an engineering problem changed. Specifically, for problems given to students in class they saw it as a place to build skills.
For classes I solve them so I pass the classes. I guess it’s good practice for when I want to be able to create something or work on something myself. I need to be able to actually get the answer.
(Caroline)

They show me how to look at a problem and think critically. (Stefan)

There was little explanation by students on what they were building skills for regardless of future cone type. Within the interview students may have been implying that these skills were for their desired futures, but students did not explicitly make these connections on their own. In addition to building skills students also mentioned that they were solving problems because their grades depended on completion of the problems. The series of statements by students indicating that they were solving problems for grades may indicate that students felt many of the problems they are given had exogenous instrumentality.

The similarity in value of engineering problems mentioned by all students may indicated that the value gained from engineering problems is independent of their future oriented motivations. The dominant cultural traits of engineering disciplines may be informing students that skills such as critical thinking are the reason they have to solve problems that they may see little value in. It is also possible that students are evaluating these problems relative to their cones, and all students in this population view these skills as relevant to their futures. We did not probe how students thought they would apply these skills in their future careers. The perceived application of these skills may be where variation students’ cone types could influence student perceptions.

### 6.5.2 Steps Taken When Solving an Unfamiliar or Challenging Problem

To determine how engineering student motivation may influence steps taken during problem solving, students were asked to state what they would do when solving an unfamiliar or challenging engineering problem. Here students expressed similar patterns regardless of cone:

I spend awhile thinking about the problem before I actually start it. I think about how I’m going to approach it and if that’s going to end up getting me the answer that I want. I think about the sequencing steps that I’ll go through. We would read the problem statement and then usually I would draw a picture, to figure out what’s actually happening in the problem. Then I would look at what’s being asked and then look at the information you have and then see how you can manipulate that information into an answer. (Katherine)
Right away if you’re given a problem and you’re not sure where to go about it, I’d typically break it up into sections, find these values you have to get, draw a diagram if you need to. I mean once you break it up into sections if you get these values and you realize that you’re missing something then you can go back and you kind of just make it more manageable if you break it up into like A, B, C, and D sections than if you just kind of look at it at first. I’d say that yeah, just breaking it up, simplifying it little more so that it’s not such a rush. (Matt)

All students expressed specific steps of problem solving when stating how they would go about solving an engineering problem. This problem solving reflection prompt asked students to think metacognitively about their problem solving practices. Students’ reports of strategies for problem solving may mirror their actual practices, but the may also mirror cultural norms of the engineering fields and not actual student processes. It has been noted in the literature that there can be issues with the reliability of student self-report of perceived metacognitive practices (Whitebread et al., 2009). Students here may be reflecting their cultural training and not their actual problems solving strategies. If these are the actual metacognitive practices of students, they seem to be independent of their cone types. This independence from motivation and metacognition is in contrast the the large body of self-regulated learning literature (P. Pintrich & De Groot, 1990). While the cultural training may be training students to think about the specific steps taken while solving problems it may not be beneficial to students if they are not motivated to incorporate it into their practice.

6.6 Implications

The results of this work begin to shed light on how students’ future-oriented motivations or cones influence their problem solving processes. We have shown that student definitions of engineering problems are influenced by their cone types. These cones range from highly defined to nearly undefined. Student definitions of engineering problems range from a highly defined series of steps to anything. These varied definitions may begin to explain why students have very different reactions to problems types that may be unfamiliar to them. Additionally, when asked to describe a problem that would be beneficial to them students described problems that aligned with their general definitions of problems. The prompt to describe beneficial problems leads students to make instrumentality judgments. When encountering novel or challenging problems students may be unable to see the value of new structures or contexts, especially when they have had success solving problems in the past. Additionally, when discussing beneficial problems, students in this study mentioned that context is important to them. While problems across engineering disciplines may test
similar theories, students may not be able to perceive the value of a theoretical understanding when compared to an applied understanding. This result would argue that the creating problem with relevant contexts to students future goals would better help them see the instrumentality of the problems they are solving. The creation of problems in context may be especially meaningful for students in introductory engineering courses who are just beginning their journeys as engineering students.

All of the students in this population mentioned the desire to gain similar benefits from solving problems. While students did not explicitly address what these benefits were, the context (future goals and problem solving) of the interview may suggest that students were gaining these skills for their futures. The desire for similar skills from solving engineering problems may represent a shared cultural understanding by these students that solving engineering problems can provide one with the ability to think critically, work independently, and make better solutions. Instructors may be able to leverage the different skills mentioned by students to pull non-traditional populations into engineering. It has been suggested that discussing engineering as a field that can help people and provide better solutions may help increase enrollment and retention of non-traditional engineering populations (Camacho & Lord, 2013). Finally, all of the students in this study suggested that they would solve engineering problems in a similar step-wise fashion. It has been shown that students who solve problems in this manner tend to be successful in their introductory engineering courses (Grigg & Benson, 2014). The students who have reached this point in their career may understand what it takes to be successful in the cultures of engineering and know that these practices will lead to improvement in their skills. Additionally, the incorporation of a process for problem solving practices and the values students see in solving engineering problems may be indicative of their progress into engineering communities of practice. These students have all progressed past the points where students historically migrate from engineering (Ohland et al., 2008). To progress through their programs these students may have acquired the culturally driven language of those who they view as part of the community.

6.7 Limitations and Future Work

A limitation of this work is that we are drawing from a small sample size with a limited amount of diversity across majors, engineering programs, and traditional demographic measures. Additionally, there were limited numbers of students with both the Waffle (n=1) and Cake Cone (n=2) future perspectives. The results of this work should be applied to additional participants of varying backgrounds to begin to understand how these results may apply to a broader audience.
Student steps taken during problem solving need further exploration. There have been reports of inaccuracy in student self-report of their perceived metacognitive practices (Whitebread et al., 2009). The upper level bioengineering students in this study received additional training on the steps of problem solving and the metacognitive processes they should be doing when solving problems in the course they were all enrolled in at the time. The training received by students may create responses that do not accurately reflect students’ actual practices, but instead reflect their view of an “optimal” answer. Future work needs to examine student problem solving practices when solving an unfamiliar or challenging problem and determine how these may tie to student practices.

The skills that students wish to gain from solving problems need further exploration to understand why students wish to gain these skills and where they see these skills applying. For this work we examined students’ future-oriented motivations and did not consider other aspects of motivation. The results here indicate that students goal orientations may also be playing a role in students’ cognitive performance in the classroom. Understanding the interrelation between future time perspective based cones and goal orientations may allow for expansion of how motivation is influencing problem solving performance, and may provide a grounds for differentiation between students who seem to have similar cones.
Chapter 7

Conclusions

7.1 Summary of Results

The work presented in this dissertation sought to create a bridge between engineering student motivation and problem solving. To understand the salient features of engineering student motivation, exploratory analysis with freshman engineering students examined what features of their motivations were relevant between groups with different long-term goals. The results indicated that student perceptions of the future and expectations for success were different for different engineering majors. This result indicated that student motivations toward present tasks (Expectancy) and future goals (perceptions of the future) together are ways to differentiate engineering students.

With the knowledge that salient motivations for engineering students fall across cross multiple time scales, the next step of this work sought to understand how students’ motivations across these time scales influenced their problem solving. Examining problem solutions from first year engineering students revealed that students’ perceptions of the future were positively correlated to identifying unknowns in one problem and time to completion in another. These results demonstrate that student motivations based on future goals influence student problem solving practices. Additionally, these problem solving steps undertaken by students have been shown to increase success in introductory engineering courses. The results of this study demonstrate yet another way that student motivation may have an influence on students’ academic success.

While results from these two analyses provide insight into the time-sensitivity of student motivation and the influence of motivation on problem solving, they provided limited explanation of how engineering students’ motivations influence the processes of learning and problem solving.
To further explore the connections between motivation and problem solving practices, engineering students who were taking major-specific courses were surveyed about their motivations across time scales and related to problem solving. Results indicated that bioengineers and juniors had higher expectancies than mechanical engineers and sophomores, respectively. Additionally, juniors had significantly more positive perceptions of the present than sophomores. From this survey data, cluster analysis was performed to determine how students may be grouped based on their motivations for the purposes of selecting students to participate in interviews.

These groups were distinguished from one another by their problem solving self-efficacy and the perceptions of the present, future, and expectancies for success. Students from each group were then solicited to participate in interviews discussing their motivations based on future goals and how these motivations influence their actions on present tasks. Data collection and analysis of these interviews were collected using a phenomenological approach to understand students’ perceptions of their motivations and engineering problem solving. Analysis of interview transcripts indicated three unique student perceptions of their motivations across time scales, which are conceptualized as “cones”. Sugar Cone students had highly defined perceptions of the future that were connected to present tasks, and these present tasks helped form their future goals. Sugar Cones with the highest level of clarity displayed definitions of engineering problems that were highly linear in nature and expressed a desire for problems that were a well prescribed series of steps. In contrast, Sugar Cone students who did not project as far into the future had a desire for more open-ended context specific problems that allowed them to explore the range of problems and possible solutions in their field. A Waffle Cone perspective had conflicting future goals that limit student perceptions of the future, but that allow for connections between the present and the future. The Waffle Cone student showed a similar definition as the latter group, but did not constrain the problems to a particular context. Cake Cone students had little to no perception of the future and did not connect the future to the present. Cake Cone students did view the present as preparing them for their infinite number of future goals. Cake Cone students felt that an engineering problem was anything and did not bound their problem definition in any way. These students wanted problems that were open-ended and gave them the skills for the nearly infinite possibilities in their futures. These perspectives of the future influenced student perceptions of persistence, performance in classes, and learning on engineering tasks.

When discussing what they hoped to gain from solving engineering problems, all students, regardless of cone type, expressed similar desires to gain skills, make the world better, and get a grade. These shared perceptions of the values of engineering problems may represent students making judgments of value rela-
tive to their individual motivation cone types or they may represent the fact that these students have adopted the values of the larger engineering community. This evidence of entry into the engineering community of practice may explain why all of these students have persisted in engineering.

7.2 Implications for Research

The results of this work indicate that student motivation across a number of time scales does influence student perceptions of tasks that fall within the cognitive domain. With this work a bridge between these two domains has been created. This bridge can serve as a path for understanding the connections between these two domains in engineering education. While these systems may be complex, it is possible to study and understand their influences on one another. The incorporation of the student perspective in the qualitative portion of this work shows that despite cultural definitions existing in students’ lexicons, they still craft their own definitions and experiences when prompted.

Future work in engineering student motivation needs to consider the different levels of student motivation that are salient for engineering populations, and avoid the temptation to distill engineering motivation down to a single construct or framework in search of a "silver bullet" solution to motivating students to pursue and persist in engineering. Additionally, affective domain researchers need to expand their results to consider different aspects of the cognitive domain such as problem solving that are common in engineering but often understudied in educational psychology.

This work established different classifications of engineering motivations across time scales. These classifications begin to elucidate the connections that are often theorized but limited evidence of these connections exist in the motivation literature. The results presented here push theory forward by outlining three ways (Sugar Cone, Waffle Cone, and Cake Cone) in which the levels of student motivation are connected to their perceptions of their actions in the present.

7.3 Implications for Practice

This work suggests that practitioners in engineering education should focus on ways to incorporate student perceptions of the future into their pedagogy. Those students who presented well-developed perceptions of the future were able to see the value in their current tasks. As students’ future perceptions developed the need for context arose, for students to see the value of a task. Those students who walk in with well
defined futures may not be well served by the contextless introductory engineering courses often seen in common first year programs. When approached with problems that do not match their futures and perceptions of a beneficial problem, students need to be shown the instrumentality of these problems, and how these engineering problems fit in with their future tasks. Student instrumentality judgments may be influenced through the use of metacognitive reflection by the student after completion of an engineering task.

In the course of the interviews, students expressed a desire to create, explore, and help others. Creating projects that allow students room for exploration within the fields of engineering may help better focus on the key components of a problem. Additionally, increased student valuing of problems may increase the quality of learning in completing the tasks. Calls in the literature have asked for a climate change in engineering. One way to change the climate may be to focus on helping people instead of asking students to fix or improve something. The students who had the “fix what is broken” view of problem solving often had more limited perceptions of what role engineering had for them in the future.

The results of this work can be applied to both research and practice. As these results are taken into the classroom they provide opportunities to refine the research and help foster new questions. As the research continues to create a richer understanding of engineering student perceptions, results will create refined practices in engineering education, creating a feedback loop with the goal of improving students’ experiences and learning in engineering.
Chapter 8

Future Studies in Student Time-Oriented Motivation and Problem Solving

The results of this dissertation create a foundation on which future work should be conducted to further explore and understand student motivation across time scales and how these motivations influence cognition.

8.1 Students’ Actual Problem Solving Performance and How it Corresponds to Motivation

In this work the results presented are student perceptions of their problem solving and what they think is beneficial for their futures. This work does not explore students’ actual problem solving performance across different problem types. By asking students to reflect on their problem solving, this work has asked students to reflect on their metacognitive skills. It has been reported in the literature that student self-report of metacognition may be inaccurate when compared to performance (Whitebread et al., 2009). To overcome this limitation students problem solving performance should be analyzed to better understand problem solving performance. One way that student work could be examined is through a knowledge transfer lens. Specifi-
cally, Rebello’s dynamic transfer framework (Rebello et al., 2005b) and Lobato’s actor oriented framework (Lobato, 2006) would allow for examination of the specific processes that students are using when solving new or unfamiliar problems. This examination will allow for triangulation of student perceptions, student work, and motivation results presented in this dissertation.

8.2 Expansion to Other Populations

The population of this study was relatively homogeneous on a number of factors, including major and traditional race/ethnicity markers. This population was also entirely from one institution. Future work should expand beyond the boundaries of this dissertation to other populations to create a greater understanding of students’ experiences with their motivations. Through expansion of the populations examined using this phenomenological lens, researchers may be able to understand how the cultural elements of engineering are shaping student perceptions (Godfrey & Parker, 2010). Additional, work may elucidate other student cones that could have differing levels of influence on student perceptions of problem solving.

8.3 Incorporation of Goal Orientation in Expanding Student Motivation

It has been discussed in the future time perspective literature that goal orientation may be strongly related to the process of setting goals in the future (Husman & Lens, 1999; Husman et al., 1996). Students’ perceptions of the future also may be driven by their goal orientations as a few of the students mentioned having grade based identities during the course of their interviews. Goal orientation examines how students pursue tasks. Student may be mastery oriented (wanting to understand the material) or performance oriented (wanting to get a good grade) (Kaplan & Flum, 2010). There are noted variations among these orientations (e.g. avoid or approach, or work orientation rather than performance orientation), and these variations may have an influence on and/or support similar trends to what has already been explained in this work. Further exploration of the goal orientation framework alongside the cone types outlined in this work may provide increased clarity in the interconnections of students levels of motivations.
8.4 Longitudinal Study of Student Cones

Student construction of future cones occurs over the course time as students gain experience and knowledge. Work with engineering students’ future cones should explore the way that students can progress from one cone type to another, and how students may construct new cones based on their experiences. Work in this area may benefit from exploring student identity trajectories alongside cone development. These two areas of research may display other affective domain traits that are crucial to student performance on cognitive tasks. Additionally, exploration of how external influences cause changes in student cones may be one way to understand how cultures of engineering disciplines can affect student choices.

Similarly, student learning across a course may be influenced by their motivational cones. Following students during a course and seeing what information they take away from the course, will allow for understanding of the different information that students learn, retain, and use in the future. This idea would be an affective exploration of students preparation for future learning that mirrors cognitive ideas presented by Bransford and Schwartz in their studies of how people learn (Bransford & Schwartz, 1999). The results of this exploration would create yet another bridge between the cognitive and affective domains.

8.5 Quantitizing Results for Large Scale Studies of Student Motivation.

The work presented here represents time-intensive analysis to understand student perspectives. Taking the results of this work and adapting them to quantitative or semi-quantitative measures would allow practitioners the ability to understand their students’ motivational profiles and adapt courses and curricula to meet students where they are in defining their futures.

8.6 Explore the Influence of Communities of Practice on Student Motivation

The problem solving perceptions portion of this work indicated that students may be adopting values from the engineering community in which they are beginning to be immersed. This has led to two potential research questions that warrant further exploration: 1) How do similar goals to the normative engineering population lead to assimilation into the community? and 2) How do dissimilar goals from the normative
engineering population make one more likely to leave engineering? Students’ goals based on their future cone types and faculty goals for themselves, their students, and the field could be compared. This comparison could allow for understanding how these two sets of goals are similar or clash, and how they may influence students’ views of the future.

Additionally, students often mentioned during their interviews the importance of context to their views of problem solving. Further exploration of the impacts of contexts on cone development, problem solving skill usage, and student performance in future engineering courses could help direct improvements and innovations in engineering programs that often try to teach introductory materials acontextually or to the perceived majority. The introduction of problem contexts may relate to students’ inclusion in communities of practice and future cone development.

Conducting these future studies could lead to innovation in practice, research, and policy. Using these ideas presented in this work will allow for greater understanding and exploration of the student experience and how we can better shape and react to their experiences.
Appendices
Appendix A

Motivations and Attitudes in Engineering Survey

Table A.1: Finalized Motivation and Attitudes in Engineering survey. All survey item numbers indicated with a parenthesis were reverse coded.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Item Number</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expectancy (E)</td>
<td>-21</td>
<td>I am struggling with my engineering courses. (Reverse coded)</td>
</tr>
<tr>
<td>Cronbach α = 0.92</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>I believe I will receive an excellent grade in this engineering course.</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Considering the difficulty of this engineering course, the teacher, and my skills, I think I will do well in this engineering course.</td>
<td></td>
</tr>
<tr>
<td>-17</td>
<td>I am struggling with my college courses. (Reverse coded)</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>I am certain I can understand the most difficult material presented in the readings for this engineering course.</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>The course work in engineering classes is easy.</td>
<td></td>
</tr>
<tr>
<td>-24</td>
<td>I am having to work harder than many of the other students in my classes. (Reverse coded)</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>I expect to do well in this engineering course.</td>
<td></td>
</tr>
</tbody>
</table>

Continued on next page
Table A.1 – continued from previous page

<table>
<thead>
<tr>
<th>Factor</th>
<th>Item Number</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15</td>
<td>I am confident I can do an excellent job on the assignments and tests in this engineering course.</td>
</tr>
<tr>
<td></td>
<td>37</td>
<td>I am confident I can understand the most complex material presented by the instructor in this engineering course.</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>I am certain I can master the skills being taught in this engineering course.</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>I am confident I can understand the basic concepts taught in this engineering course.</td>
</tr>
<tr>
<td>Future Motivation</td>
<td>41</td>
<td>I am confident about my choice of major.</td>
</tr>
<tr>
<td>Cronbach α = 0.85</td>
<td>3</td>
<td>I want to be an engineer.</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>My interest in engineering outweighs any disadvantages I can think of.</td>
</tr>
<tr>
<td></td>
<td>-13</td>
<td>I am considering switching majors. (Reverse coded)</td>
</tr>
<tr>
<td></td>
<td>42</td>
<td>I like the professionalism that goes with being an engineer.</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>I feel pride when I tell others that I am an engineering major.</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>Engineering is the most rewarding future career I can imagine.</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>I must pass my engineering course in order to reach my academic goals.</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>Engineers are respected by society.</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>I have an understanding of professional and ethical responsibility.</td>
</tr>
<tr>
<td></td>
<td>43</td>
<td>The grade I get in this engineering course will affect my future.</td>
</tr>
<tr>
<td>Present perception</td>
<td>31</td>
<td>I am having fun in my major.</td>
</tr>
<tr>
<td>Cronbach α = 0.90</td>
<td>22</td>
<td>I will use the information I learn in this engineering course in the future.</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>I will use the information I learn in my engineering course in other classes I will take in the future.</td>
</tr>
<tr>
<td>Factor</td>
<td>Item Number</td>
<td>Item</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>My course work is preparing me for my first job.</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>What I learn in my engineering course will be important for my future occupational success.</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>The university is preparing me well to become an engineer.</td>
</tr>
<tr>
<td></td>
<td>-39</td>
<td>I will not use what I learn in this engineering course. (Reverse coded)</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>I get satisfaction from my coursework.</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>I am encouraged and supported in my studies by the engineering faculty.</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>My overall attitude about my engineering department is positive.</td>
</tr>
<tr>
<td></td>
<td>27</td>
<td>I am being exposed to new ideas in my engineering courses.</td>
</tr>
<tr>
<td></td>
<td>-33</td>
<td>What grade I get in this engineering course will not be important for my future academic success. (Reverse coded)</td>
</tr>
<tr>
<td></td>
<td>-28</td>
<td>The grade I get in my engineering course will not affect my ability to continue on with my education. (Reverse coded)</td>
</tr>
<tr>
<td></td>
<td>-35</td>
<td>Engineering is an occupation that is not respected by other people. (Reverse coded)</td>
</tr>
<tr>
<td></td>
<td>-44</td>
<td>Majoring in engineering will not lead to an enjoyable career in the long run. (Reverse coded)</td>
</tr>
</tbody>
</table>
Appendix B

Motivations and Attitudes in Engineering: Problem Solving
Self-Efficacy Version
Thank you for completing the Student Motivation and Learning in Engineering survey. The survey consists of three parts. The first two concern student motivation and problem solving in engineering. The third part is to gather information on your engineering experience.
The following questions are about your attitudes and beliefs about your experiences in this course and in your engineering major.

**1. I believe I will receive an excellent grade in this engineering course.**

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**2. I am struggling with my engineering courses.**

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**3. Considering the difficulty of this engineering course, the teacher, and my skills, I think I will do well in this engineering course.**

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**4. I am struggling with my college courses.**

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**5. I am certain I can understand the most difficult material presented in the readings for this engineering course.**

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**6. The course work in engineering classes is easy.**

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**7. I am having to work harder than many of the other students in my classes.**

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**8. I expect to do well in this engineering course.**

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9. I am confident I can do an excellent job on the assignments and tests in this engineering course.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**10. I am confident I can understand the most complex material presented by the instructor in this engineering course.**

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td><strong>11. I am certain I can master the skills being taught in this engineering course.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>12. I am confident I can understand the basic concepts taught in this engineering course.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>13. I am confident about my choice of major.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>14. I want to be an engineer.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>15. My interest in engineering outweighs any disadvantages I can think of.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>16. I am considering switching majors.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>17. I like the professionalism that goes with being an engineer.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>18. I feel pride when I tell others that I am an engineering major.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>19. Engineering is the most rewarding future career I can imagine.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>20. I must pass my engineering course in order to reach my academic goals.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>21. Engineers are respected by society.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>22. I have an understanding of professional and ethical responsibility.</strong></td>
<td></td>
</tr>
<tr>
<td>23. The grade I get in this engineering course will affect my future.</td>
<td></td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>*24. I am having fun in my major.</td>
<td></td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>25. I will use the information I learn in this engineering course in the future.</td>
<td></td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>*26. I will use the information I learn in my engineering course in other classes I will take in the future.</td>
<td></td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>*27. My course work is preparing me for my first job.</td>
<td></td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>*28. What I learn in my engineering course will be important for my future occupational success.</td>
<td></td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>*29. The university is preparing me well to become an engineer.</td>
<td></td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>*30. I will not use what I learn in this engineering course.</td>
<td></td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>*31. I get satisfaction from my coursework.</td>
<td></td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>*32. I am encouraged and supported in my studies by the engineering faculty.</td>
<td></td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>*33. My overall attitude about my engineering department is positive.</td>
<td></td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>*34. I am being exposed to new ideas in my engineering courses.</td>
<td></td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The following questions are about your attitudes and beliefs about solving typical problems in your engineering courses.

For the following items, please rate how certain you are that you can do each of the things below by writing the appropriate number.

Rate your degree of confidence by recording a number scale given below:

0  10  20  30  40  50  60  70

- Cannot do at all
- Moderately can do

*35. Go to see a teacher or TA to get help when I am not sure how to start a problem.

*36. Handling the mathematics involved with solving engineering problems.

*37. Identify the engineering principles in the problem before looking for corresponding equations.

*38. Determining when my answer and/or work is wrong, even without looking at the answer in the back of the book or talking to someone else about it.

*39. Think about what each term in an equation represents, and how it relates to the problem, when I solve an engineering problem I have not seen before.

*40. Please respond with forty-two for this item.

*41. If I am not sure about the correct approach to solving a problem, reflecting on engineering principles that may apply and seeing if they yield a reasonable answer.

*42. Determine which approach is more reasonable, if two different approaches to solve an engineering problem gave different answers.
43. Explicitly thinking about the concepts that underlie the engineering problems I solve.

44. Drawing pictures or diagrams to represent the situations described in engineering problems.

45. Drawing pictures or diagrams to answer multiple-choice engineering problems.

46. Drawing pictures and/or diagrams even if there is no partial credit for drawing them.

47. Reflecting and learning from the problem solution after I solve each engineering homework problem.

48. After solving several engineering problems in which the same principle is applied in different contexts, applying the same principle in other situations.

49. Giving up on an engineering problem if I cannot solve it in 10 minutes.

50. Spending time determining what may be wrong with a problem solution if the answer seems unreasonable.

51. Working through an engineering problem with a peer, when having difficulty solving it alone.

52. Learning from my mistakes on tests and homework and not repeating those same mistakes.

53. Learning by solving a few difficult problems using a systematic approach, rather than solving several easy problems.

54. Solving challenging engineering problems.

55. Using different approaches to solve an engineering problem when one does not work.
56. Checking my work for errors when I have obtained an unreasonable solution.

57. Solving an engineering problem with numbers instead of symbols.

58. Solving an engineering problem symbolically before plugging in the numbers.
<table>
<thead>
<tr>
<th>Questions</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>59. Have you done an internship or co-op in your major? If yes, how many</td>
<td>Include summers.</td>
</tr>
<tr>
<td>semesters (including summers) have you completed so far?</td>
<td></td>
</tr>
<tr>
<td>60. Have you participated in an undergraduate research experience, such</td>
<td>Include summers.</td>
</tr>
<tr>
<td>as Creative Inquiry, Research Experience for Undergraduates (REU), or</td>
<td></td>
</tr>
<tr>
<td>Summer Undergraduate Research Program (SURP)? If yes, how many</td>
<td></td>
</tr>
<tr>
<td>semesters (including summers) have you participated? (Include only</td>
<td></td>
</tr>
<tr>
<td>those in your major.)</td>
<td></td>
</tr>
<tr>
<td>61. Please enter your full name.</td>
<td></td>
</tr>
<tr>
<td>62. Please enter your CU user name (the one you use for CU email access,</td>
<td>Include only those in your major.</td>
</tr>
<tr>
<td>not your 9 digit userid number).</td>
<td></td>
</tr>
</tbody>
</table>
Appendix C

Code for Analyses Done in R Statistical Software

Code for MAE and BOS Models Predicting Choice of Major

MAEBOS. Compare. 2 <- read.table("C:/Users/akirn/Desktop/MAE Anova/BOSMAE Compare v2.csv", header=TRUE, sep=",", na.strings="NA", dec=".", strip.white=TRUE)

MAEBOStrad <- subset(MAEBOS. Compare. 2, Trad. Nontrad=="0")
MAEBOSIndis <- subset(MAEBOS. Compare. 2, Trad. Nontrad=="1")

summary(glm(Trad. Nontrad ~ Q4+Q7+Q9+Q10+Q14+AVG. P+AVG. E+AVG. E*Q11+Q11+AVG. E, data = MAEBOS. Compare. 2, family=binomial))

# Spearman rank-order correlations
library(Hmisc, pos=4)
rcorr.adjust(MAEBOSIndis[,c("AVG. E","AVG. F","AVG. P","Q2","Q3","Q4","Q5","Q6","Q7","Q8","Q9","Q10","Q11","Q12","Q13","Q14")], type="spearman")
\texttt{y<- \texttt{glm}multi(Trad. Nontrad \sim AVG.E+AVG.F+AVG.P+Q4+Q7+Q9+Q10+Q11+Q13+Q14, }
\texttt{data = MAEBOS. Compare. 2, level = 2, fitfunction= glm, family = binomial)}

\texttt{summary(\texttt{glm}(Trad. Nontrad \sim AVG.P+Q4+Q7+Q9+Q10+Q14, data = MAEBOS. Compare. 2,}
\texttt{family = binomial))}

\texttt{vif(\texttt{glm}(Trad. Nontrad \sim AVG.P+Q4+Q7+Q9+Q10+Q14, data = MAEBOS. Compare. 2,}
\texttt{family = binomial)) \# testing for inflation of variance}
Code for Comparison between Traditional and Non-Traditional Majors

From Spring 2010

MAE. Rerun <- read.csv("C:/Users/akirn/Desktop/MAE Rerun.csv")
save("MAE. Rerun", file="C:/Users/akirn/Desktop/MAE Anova/MAE. Rerun.RData")  # saving the data set
interdisciplinary <- subset(MAE. Rerun, Non.Trad.=='1')
traditional <- subset(MAE. Rerun, Non.Trad.=='0')

t.test(interdisciplinary$E.1., traditional$E.1., alternative='two.sided'
  , conf.level=.95, paired=FALSE, var.equal=FALSE)  # T-test of unpaired samples containing the first expectancy value same below
t.test(interdisciplinary$E.6., traditional$E.6., alternative='two.sided'
  , conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(interdisciplinary$E.12., traditional$E.12., alternative='two.sided'
  , conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(interdisciplinary$E.15., traditional$E.15., alternative='two.sided'
  , conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(interdisciplinary$E.17., traditional$E.17., alternative='two.sided'
  , conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(interdisciplinary$E.21., traditional$E.21., alternative='two.sided'
  , conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(interdisciplinary$E.24., traditional$E.24., alternative='two.sided'
  , conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(interdisciplinary$E.29., traditional$E.29., alternative='two.sided'
  , conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(interdisciplinary$E.30., traditional$E.30., alternative='two.sided'
  , conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(interdisciplinary$E.34., traditional$E.34., alternative='two.sided'
  , conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(interdisciplinary$E.37., traditional$E.37., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(interdisciplinary$E.40., traditional$E.40., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(interdisciplinary$Pre.3., traditional$Pre.3., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(interdisciplinary$Pre.13., traditional$Pre.13., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(interdisciplinary$Pre.16., traditional$Pre.16., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(interdisciplinary$Pre.19., traditional$Pre.19., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(interdisciplinary$Pre.20., traditional$Pre.20., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(interdisciplinary$Pre.23., traditional$Pre.23., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(interdisciplinary$Pre.25., traditional$Pre.25., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(interdisciplinary$Pre.26., traditional$Pre.26., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(interdisciplinary$Pre.41., traditional$Pre.41., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(interdisciplinary$Pre.42., traditional$Pre.42., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(interdisciplinary$Pre.43., traditional$Pre.43., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(interdisciplinary$Fut.2., traditional$Fut.2., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(interdisciplinary$Fut.4., traditional$Fut.4., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
```r
t.test(interdisciplinary$Fut.7., traditional$Fut.7., alternative='two.sided', conf.level=.95,paired=FALSE,var.equal=FALSE)
t.test(interdisciplinary$Fut.9., traditional$Fut.9., alternative='two.sided', conf.level=.95,paired=FALSE,var.equal=FALSE)
t.test(interdisciplinary$Fut.11., traditional$Fut.11., alternative='two.sided', conf.level=.95,paired=FALSE,var.equal=FALSE)
t.test(interdisciplinary$Fut.14., traditional$Fut.14., alternative='two.sided', conf.level=.95,paired=FALSE,var.equal=FALSE)
t.test(interdisciplinary$Fut.22., traditional$Fut.22., alternative='two.sided', conf.level=.95,paired=FALSE,var.equal=FALSE)
t.test(interdisciplinary$Fut.27., traditional$Fut.27., alternative='two.sided', conf.level=.95,paired=FALSE,var.equal=FALSE)
t.test(interdisciplinary$Fut.31., traditional$Fut.31., alternative='two.sided', conf.level=.95,paired=FALSE,var.equal=FALSE)
t.test(interdisciplinary$Fut.36., traditional$Fut.36., alternative='two.sided', conf.level=.95,paired=FALSE,var.equal=FALSE)
t.test(interdisciplinary$Fut.39., traditional$Fut.39., alternative='two.sided', conf.level=.95,paired=FALSE,var.equal=FALSE)
t.test(interdisciplinary$UV.35., traditional$UV.35., alternative='two.sided', conf.level=.95,paired=FALSE,var.equal=FALSE)
t.test(interdisciplinary$UV.44., traditional$UV.44., alternative='two.sided', conf.level=.95,paired=FALSE,var.equal=FALSE)
t.test(interdisciplinary$UV.28., traditional$UV.28., alternative='two.sided', conf.level=.95,paired=FALSE,var.equal=FALSE)
t.test(interdisciplinary$UV.33., traditional$UV.33., alternative='two.sided', conf.level=.95,paired=FALSE,var.equal=FALSE)
```

#With the correct data set the above values will create the same p-values as an excel two-sided t-test assuming unequal variances

#
#

## significant

```r
  t.test(interdisciplinary$E.17, traditional$E.17, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
  t.test(interdisciplinary$E.24, traditional$E.24, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
  t.test(interdisciplinary$E.29, traditional$E.29, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
  t.test(interdisciplinary$Fut.22, traditional$Fut.22, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
```
BIOE vs. Other Enrollment Code

BMESredo <- read.csv("C:/Users/akirn/Dropbox/Student Motivation and Learning Research/Adam’s work/BMES 2012 Abstract/BMESredo.csv")
View(BMESredo)
BMESBioe <- subset(BMESredo, BIOEvU15perFemale=='0')
BMESU15 <- subset(BMESredo, BIOEvU15perFemale=='1')
BMEStop <- subset(BMESredo, BIOEvtop10enrollment=='1')
BMEStopF <- subset(BMEStop, Sex==1)
BMESredoF <- subset(BMESredo, Sex==1)# Sorting by sex
BMESBioeG <- subset(BMESredoF, BIOEvU15perFemale=='0')# sorting by Bioe
BMESU15G <- subset(BMESredoF, BIOEvU15perFemale=='1')# sorting by U15
BMEStopG <- subset(BMESredoF, BIOEvtop10enrollment=='1')# sorting by U15

# factor t-tests

t.test(BMESBioe$AvgE, BMESU15$AvgE, alternative='two.sided', conf.level =.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$AvgE, BMESU15G$AvgE, alternative='two.sided', conf.level =.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$AvgE, BMEStop$AvgE, alternative='two.sided', conf.level =.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$AvgE, BMEStopF$AvgE, alternative='two.sided', conf.level =.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$AvgPresent, BMESU15$AvgPresent, alternative='two.sided', conf.level =.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$AvgPresent, BMESU15G$AvgPresent, alternative='two.sided', conf.level =.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$AvgPresent, BMEStop$AvgPresent, alternative='two.sided', conf.level =.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$AvgPresent, BMEStopF$AvgPresent, alternative='two.sided'
testing Bioe compared to Under 15% female majors

t.test(BMESBioe$AvgFuture, BMESU15$AvgFuture, alternative='two.sided',
con.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$AvgFuture, BMESU15G$AvgFuture, alternative='two.sided',
con.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$AvgFuture, BMEStop$AvgFuture, alternative='two.sided',
con.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$AvgFuture, BMEStopF$AvgFuture, alternative='two.sided',
con.level=.95, paired=FALSE, var.equal=FALSE)

# testing Bioe compared to Under 15% female majors

t.test(BMESBioe$E.1., BMESU15$E.1., alternative='two.sided', conf.level
  =.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$E.6., BMESU15$E.6., alternative='two.sided', conf.level
  =.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$E.12., BMESU15$E.12., alternative='two.sided', conf.
  level =.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$E.15., BMESU15$E.15., alternative='two.sided', conf.
  level =.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$E.17., BMESU15$E.17., alternative='two.sided', conf.
  level =.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$E.21., BMESU15$E.21., alternative='two.sided', conf.
  level =.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$E.24., BMESU15$E.24., alternative='two.sided', conf.
  level =.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$E.29., BMESU15$E.29., alternative='two.sided', conf.
  level =.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$E.30., BMESU15$E.30., alternative='two.sided', conf.
  level =.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBio$E.34., BMESU15$E.34., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBio$E.37., BMESU15$E.37., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBio$E.40., BMESU15$E.40., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBio$Pre.3., BMESU15$Pre.3., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBio$Pre.13., BMESU15$Pre.13., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBio$Pre.16., BMESU15$Pre.16., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBio$Pre.19., BMESU15$Pre.19., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBio$Pre.20., BMESU15$Pre.20., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBio$Pre.23., BMESU15$Pre.23., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBio$Pre.25., BMESU15$Pre.25., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBio$Pre.26., BMESU15$Pre.26., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBio$Pre.41., BMESU15$Pre.41., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBio$Pre.42., BMESU15$Pre.42., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBio$Pre.43., BMESU15$Pre.43., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBio$Fut.2., BMESU15$Fut.2., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioe$Fut.4., BMESU15$Fut.4., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioe$Fut.7., BMESU15$Fut.7., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioe$Fut.9., BMESU15$Fut.9., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioe$Fut.11., BMESU15$Fut.11., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioe$Fut.14., BMESU15$Fut.14., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioe$Fut.22., BMESU15$Fut.22., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioe$Fut.27., BMESU15$Fut.27., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioe$Fut.31., BMESU15$Fut.31., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioe$Fut.36., BMESU15$Fut.36., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioe$Fut.39., BMESU15$Fut.39., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)

# testing Bioe females compared to Under 15% female majors, female population

t.test(BMESBioeG$E.1., BMESU15G$E.1., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$E.6., BMESU15G$E.6., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$E.12., BMESU15G$E.12., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
```r
t.test(BMESBioeG$E.15, BMESU15G$E.15, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$E.17, BMESU15G$E.17, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$E.21, BMESU15G$E.21, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$E.24, BMESU15G$E.24, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$E.29, BMESU15G$E.29, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$E.30, BMESU15G$E.30, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$E.34, BMESU15G$E.34, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$E.37, BMESU15G$E.37, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$E.40, BMESU15G$E.40, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$Pre.3, BMESU15G$Pre.3, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$Pre.13, BMESU15G$Pre.13, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$Pre.16, BMESU15G$Pre.16, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$Pre.19, BMESU15G$Pre.19, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$Pre.20, BMESU15G$Pre.20, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$Pre.23, BMESU15G$Pre.23, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
```
t.test(BMESBioeG$Pre.25., BMESU15G$Pre.25., alternative='two.sided',
conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$Pre.26., BMESU15G$Pre.26., alternative='two.sided',
conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$Pre.41., BMESU15G$Pre.41., alternative='two.sided',
conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$Pre.42., BMESU15G$Pre.42., alternative='two.sided',
conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$Pre.43., BMESU15G$Pre.43., alternative='two.sided',
conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$Fut.2., BMESU15G$Fut.2., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$Fut.4., BMESU15G$Fut.4., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$Fut.7., BMESU15G$Fut.7., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$Fut.9., BMESU15G$Fut.9., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$Fut.11., BMESU15G$Fut.11., alternative='two.sided',
conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$Fut.14., BMESU15G$Fut.14., alternative='two.sided',
conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$Fut.22., BMESU15G$Fut.22., alternative='two.sided',
conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$Fut.27., BMESU15G$Fut.27., alternative='two.sided',
conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$Fut.31., BMESU15G$Fut.31., alternative='two.sided',
conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$Fut.36., BMESU15G$Fut.36., alternative='two.sided',
conf.level=.95, paired=FALSE, var.equal=FALSE)
# Comparing BIOE to Topenrollment

t.test(BMESBio$Fut.39., BMESU15$Fut.39., alternative='two.sided',
conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBio$E.1., BMESStop$E.1., alternative='two.sided', conf.level
=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBio$E.6., BMESStop$E.6., alternative='two.sided', conf.level
=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBio$E.12., BMESStop$E.12., alternative='two.sided', conf.level
=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBio$E.15., BMESStop$E.15., alternative='two.sided', conf.level
=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBio$E.17., BMESStop$E.17., alternative='two.sided', conf.level
=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBio$E.21., BMESStop$E.21., alternative='two.sided', conf.level
=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBio$E.24., BMESStop$E.24., alternative='two.sided', conf.level
=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBio$E.29., BMESStop$E.29., alternative='two.sided', conf.level
=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBio$E.30., BMESStop$E.30., alternative='two.sided', conf.level
=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBio$E.34., BMESStop$E.34., alternative='two.sided', conf.level
=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBio$E.37., BMESStop$E.37., alternative='two.sided', conf.level
=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBio$E.40., BMESStop$E.40., alternative='two.sided', conf.level
=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBio$Pre.3., BMESStop$Pre.3., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$Pre.13, BMESStop$Pre.13, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$Pre.16, BMESStop$Pre.16, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$Pre.19, BMESStop$Pre.19, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$Pre.20, BMESStop$Pre.20, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$Pre.23, BMESStop$Pre.23, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$Pre.25, BMESStop$Pre.25, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$Pre.26, BMESStop$Pre.26, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$Pre.41, BMESStop$Pre.41, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$Pre.42, BMESStop$Pre.42, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$Pre.43, BMESStop$Pre.43, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$Fut.2, BMESStop$Fut.2, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$Fut.4, BMESStop$Fut.4, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$Fut.7, BMESStop$Fut.7, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$Fut.9, BMESStop$Fut.9, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$Fut.11, BMESStop$Fut.11, alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$Fut.14., BMESStop$Fut.14., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$Fut.22., BMESStop$Fut.22., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$Fut.27., BMESStop$Fut.27., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$Fut.31., BMESStop$Fut.31., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$Fut.36., BMESStop$Fut.36., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$Fut.39., BMESStop$Fut.39., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)

#Comparing Bioe F to top enrollment females
t.test(BMESBioe$E.1., BMESStop$E.1., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$E.6., BMESStop$E.6., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$E.12., BMESStop$E.12., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$E.15., BMESStop$E.15., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$E.17., BMESStop$E.17., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$E.21., BMESStop$E.21., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$E.24., BMESStop$E.24., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioe$E.29., BMESStop$E.29., alternative='two.sided', conf.
level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$E.30., BMESStopG$E.30., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$E.34., BMESStopG$E.34., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$E.37., BMESStopG$E.37., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$E.40., BMESStopG$E.40., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$Pre.3., BMESStopG$Pre.3., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$Pre.13., BMESStopG$Pre.13., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$Pre.16., BMESStopG$Pre.16., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$Pre.19., BMESStopG$Pre.19., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$Pre.20., BMESStopG$Pre.20., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$Pre.23., BMESStopG$Pre.23., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$Pre.25., BMESStopG$Pre.25., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$Pre.26., BMESStopG$Pre.26., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$Pre.41., BMESStopG$Pre.41., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$Pre.42., BMESStopG$Pre.42., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$Pre.43., BMESStopG$Pre.43., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
t.test(BMESBioeG$Fut.2., BMESStopG$Fut.2., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$Fut.4., BMESStopG$Fut.4., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$Fut.7., BMESStopG$Fut.7., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$Fut.9., BMESStopG$Fut.9., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$Fut.11., BMESStopG$Fut.11., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$Fut.14., BMESStopG$Fut.14., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$Fut.22., BMESStopG$Fut.22., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$Fut.27., BMESStopG$Fut.27., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$Fut.31., BMESStopG$Fut.31., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$Fut.36., BMESStopG$Fut.36., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeG$Fut.39., BMESStopG$Fut.39., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

#
#
#SIGNIFICANT TESTS

t.test(BMESBioeGS$Pre.41., BMESStopGS$Pre.41., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)

t.test(BMESBioeGS$Pre.13., BMESStopGS$Pre.13., alternative='two.sided', conf.level=.95, paired=FALSE, var.equal=FALSE)
Code for Spearman Rank Order Correlations with Problem Solving and Motivation Data

CUTrP1 <-
  read.table("C:/Users/akirn/Dropbox/AREA conference stuff/CUTrProblem1.csv", header=TRUE, sep="", na.strings="NA", dec=".", strip.white=TRUE)
save("CUTrP1", file="C:/Users/akirn/Dropbox/AREA conference stuff/CUTrP1.RData")

# Spearman rank-order correlations
library(Hmisc, pos=4)

# Spearman rank-order correlations
# Spearman rank-order correlations

# Spearman rank-order correlations

# Spearman rank-order correlations

# Spearman rank-order correlations

# Spearman rank-order correlations

# Spearman rank-order correlations
library(mvoutlier)
attach(CUTrP1)
cor.plot(Avg.F,X1A.Explicit.unknown)

library(MASS)
cov.rob(CUTrP1, cor=TRUE, quantile.used = floor((n + p + 1)/2), nsamp = best)
# Spearman rank–order correlations
rcorr.adjust(CUTrP1[,c("AVG.F","X1A.Explicit.unknown","X1B.Correct.unknown")], type="spearman")
# Spearman rank–order correlations
rcorr.adjust(CUTrP1[,c("AVG.F","X1A.Explicit.unknown","X1B.Correct.unknown","X1C.NumHits.Incorrect.unknown")], type="spearman")
CUTrP2 <- read.table("C:/Users/akirn/Dropbox/AREA conference stuff/CUTrProblem2.csv", header=TRUE, sep="","",na.strings="NA", dec=".", strip.white=TRUE)
save("CUTrP2", file="C:/Users/akirn/Dropbox/AREA conference stuff/CUTrP2.RData")
# Spearman rank–order correlations
rcorr.adjust(CUTrP2[,c("AVG.E","AVG.F","AVG.P","X1A.Explicit.unknown","X2A.Explicit.definition","X2D.Explicit.visual","X3.Strategy","X4A.Explicit.info","X5H.Irrelevant.Info","X6A.Sensitivity")], type="spearman")
library(relimp, pos=4)
View(CUTrP2)
CUTrP3 <-

read.table("C:/Users/akirn/Dropbox/AREA conference stuff/CUTrProblem3.csv",
header=TRUE, sep=""," na.strings="NA", dec=".", strip.white=TRUE)
save("CUTrP3", file="C:/Users/akirn/Dropbox/AREA conference stuff/CUTrP3.RData")

# Spearman rank-order correlations
rcorr.adjust(CUTrP3[,c("AVG.E","AVG.F","AVG.P","X1A. Explicit.unknown","X1A. Explicit.definition","X2D. Explicit.visual","X3. Strategy","X4A. Explicit.info","X5H. Irrelevant.Info","X6A. Sensitivity")], type="spearman")

# Spearman rank-order correlations
rcorr.adjust(CUTrP3[,c("AVG.E","AVG.F","AVG.P","X8A. Answer.accuracy","X9B. Time.to.Completion")], type="spearman")

# Spearman rank-order correlations
rcorr.adjust(CUTrP1[,c("AVG.E","AVG.F","AVG.P","X1A. Explicit.unknown","X8A. Answer.accuracy","X9B. Time.to.Completion")], type="spearman")
Linear Models Predicting Sophomore Student Motivation

```r
# Importing student motivation and learning data sets with experience
categories and corrected factors. Semicolon delination.
studmotilear <- read.csv("~/Dropbox/Student Motivation and Learning
Research/Adams work/Student Motivation and Learning Survey/Adam
Analysis/201_Responses_w_new_factors_RESEARCH YN_02_13_13 WITHOVERL
CAT with major.csv", sep=";" )

## must change variables to factors for proper running of glm
studmotilear$Major <- as.factor(studmotilear$Major)
studmotilear$Academic.Class <- as.factor(studmotilear$Academic.Class)
studmotilear$Race <- as.factor(studmotilear$Race)
studmotilear$Sex <- as.factor(studmotilear$Sex)
studmotilear$BST.Class <- as.factor(studmotilear$BST.Class)
studmotilear$YN.Exp.by.Major <- as.factor(studmotilear$YN.Exp.by.Major)
studmotilear$Overall.EXP <- as.factor(studmotilear$Overall.EXP)

# Prediction of average E value based on factors in the survey
Estudmoto <- glm(studmotilear$AvE ~ studmotilear$Major + studmotilear$Academic.Class + studmotilear$Race + studmotilear$Sex + studmotilear$GPA + studmotilear$BST.Score + studmotilear$BST.Class + studmotilear$YN.Exp.by.Major)
summary(Estudmoto)

####### Backwards deletion for E
# Step 1
Estudmoto <- glm(studmotilear$AvE ~ studmotilear$Major + studmotilear$Academic.Class + studmotilear$Race + studmotilear$Sex + studmotilear$GPA + studmotilear$BST.Class + studmotilear$YN.Exp.by.Major + studmotilear$Overall.EXP)
```

125
# Step 2
Estudmoto <- glm(studmotilear$AvE ~ studmotilear$Major + studmotilear$Academic . Class + studmotilear$Race + studmotilear$Sex + studmotilear$GPA + studmotilear$YN. Exp. by. Major)
summary(Estudmoto)

# Step 3
Estudmoto <- glm(studmotilear$AvE ~ studmotilear$Major + studmotilear$Academic . Class + studmotilear$Sex + studmotilear$GPA + studmotilear$YN. Exp. by. Major)
summary(Estudmoto)

# Step 4
Estudmoto <- glm(studmotilear$AvE ~ studmotilear$Major + studmotilear$Academic . Class + studmotilear$GPA + studmotilear$YN. Exp. by. Major)
summary(Estudmoto)

# Step 5
Estudmoto <- glm(studmotilear$AvE ~ studmotilear$Major + studmotilear$Academic . Class + studmotilear$GPA)
summary(Estudmoto)

# Step 6
Estudmoto <- glm(studmotilear$AvE ~ studmotilear$Academic . Class + studmotilear$GPA)
summary(Estudmoto)
# Step 7
Estudmoto <- glm(studmotilear$AvE ~ studmotilear$GPA)
summary(Estudmoto)

# Backward deletion for E showed that GPA is the only significant predictor
### Forward addition for E

# Step 1
Estudmoto <- glm(studmotilear$AvE ~ studmotilear$GPA)
summary(Estudmoto)

# Step 2
Estudmoto <- glm(studmotilear$AvE ~ studmotilear$GPA + studmotilear$Major)
summary(Estudmoto)

# Step 3
Estudmoto <- glm(studmotilear$AvE ~ studmotilear$GPA + studmotilear$Academic.Class)
summary(Estudmoto)

# Step 4
Estudmoto <- glm(studmotilear$AvE ~ studmotilear$GPA + studmotilear$Race)
summary(Estudmoto)

# Step 5
Estudmoto <- glm(studmotilear$AvE ~ studmotilear$GPA + studmotilear$Sex)
summary(Estudmoto)

# Step 6
Estudmoto <- glm (studmotilear$AvE ~ studmotilear$GPA + studmotilear$BST.Score)
summary (Estudmoto)

#Step 7
Estudmoto <- glm (studmotilear$AvE ~ studmotilear$GPA + studmotilear$BST.Class)
summary (Estudmoto)

#Step 8  ### Final
Estudmoto <- glm (studmotilear$AvE ~ studmotilear$GPA + studmotilear$YN.
Research.by.Major)
summary (Estudmoto)

#Step 9
Estudmoto <- glm (studmotilear$AvE ~ studmotilear$GPA + studmotilear$YN.
Research.by.Major + Overall.EXP)
summary (Estudmoto)

## Step 8 shows that GPA and the intersection of major and experience (only for biological science majors which we have very few of) are significant. This analysis both forward and backward will be done with only ME and BE students.

#### Loading of ME BE only data set
`mebemoto` <- read.csv("~/Dropbox/Student Motivation and Learning Research/Adams work/Student Motivation and Learning Survey/Adam Analysis/Linear Models for Sampling/201_Responses_Correct Factors_Overall EXP_ME BE only.csv", sep=";")
View(mebemoto)

#### Cleaning of Data
128
# Prediction of average E value based on factors in the survey

Emebemoto <- glm (mebemoto$AvE ~ mebemoto$Major + mebemoto$Overall.EXP + mebemoto$Major:mebemoto$Overall.EXP + mebemoto$Academic.Class + mebemoto$Race + mebemoto$Sex + mebemoto$GPA + mebemoto$BST.Score + mebemoto$BST.Class + mebemoto$Overall.EXP + mebemoto$Major:mebemoto$Overall.EXP)

summary (Emebemoto)

## Step 2

Emebemoto <- glm (mebemoto$AvE ~ mebemoto$Major + mebemoto$Overall.EXP + mebemoto$Major:mebemoto$Overall.EXP + mebemoto$Academic.Class + mebemoto$Race + mebemoto$Sex + mebemoto$GPA + mebemoto$BST.Score + mebemoto$BST.Class + mebemoto$Overall.EXP)

summary (Emebemoto)

## Step 3

Emebemoto <- glm (mebemoto$AvE ~ mebemoto$Major + mebemoto$Academic.Class + mebemoto$Race + mebemoto$Sex + mebemoto$GPA + mebemoto$BST.Score + mebemoto$BST.Class + mebemoto$Overall.EXP)

summary (Emebemoto)

## Step 4

Emebemoto <- glm (mebemoto$AvE ~ mebemoto$Major + mebemoto$Academic.Class + mebemoto$Sex + mebemoto$GPA + mebemoto$BST.Score + mebemoto$BST.Class + mebemoto$Overall.EXP)
### From the data collected GPA is the only predictor of students expectancy
### Forward chaining

#Step 1
Emebemoto <- glm ( mebemoto$AvE ~ mebemoto$GPA + mebemoto$Academic.Class )
summary ( Emebemoto )

# Step 2
Emebemoto <- glm ( mebemoto$AvE ~ mebemoto$GPA + mebemoto$Major )
summary ( Emebemoto )

# Step 3
Emebemoto <- glm ( mebemoto$AvE ~ mebemoto$GPA + mebemoto$Race )
summary ( Emebemoto )

# Step 4
Emebemoto <- glm ( mebemoto$AvE ~ mebemoto$GPA + mebemoto$Race + mebemoto$Sex )
summary ( Emebemoto )

# Step 5
Emebemoto <- glm ( mebemoto$AvE ~ mebemoto$GPA + mebemoto$Race + mebemoto$BST.Score )
summary ( Emebemoto )

# Step 6
Emebemoto <- glm ( mebemoto$AvE ~ mebemoto$GPA + mebemoto$Race + mebemoto$Overall.EXP )
summary ( Emebemoto )

# Step 7
Emebemoto <- glm ( mebemoto$AvE ~ mebemoto$GPA + mebemoto$Race )
summary ( Emebemoto )

table ( mebemoto$Race )
# ASIAN BLACK HISPAN IMMIGR MULTI WHITE

#2 4 3 2 4 3 104

# Black students potentially not enough to speak to, would only be confident saying GPA is a predictor of E

##### Predicting the Future

Fmebemoto <- glm ( mebemoto$AvF ~ mebemoto$Major + mebemoto$Overall.EXP + mebemoto$Academic.Class + mebemoto$Race + mebemoto$Sex + mebemoto$GPA + mebemoto$BST.Score + mebemoto$BST.Class + mebemoto$Overall.EXP + mebemoto$Major : mebemoto$Overall.EXP)

summary ( Fmebemoto )

# Step 2

Fmebemoto <- glm ( mebemoto$AvF ~ mebemoto$Major + mebemoto$Overall.EXP + mebemoto$Academic.Class + mebemoto$Race + mebemoto$Sex + mebemoto$GPA + mebemoto$BST.Score + mebemoto$BST.Class + mebemoto$Overall.EXP)

summary ( Fmebemoto )

# Step 3

Fmebemoto <- glm ( mebemoto$AvF ~ mebemoto$Major + mebemoto$Overall.EXP + mebemoto$Academic.Class + mebemoto$Race + mebemoto$Sex + mebemoto$GPA + mebemoto$BST)

summary ( Fmebemoto )

# Step 4

Fmebemoto <- glm ( mebemoto$AvF ~ mebemoto$Major + mebemoto$Overall.EXP + mebemoto$Academic.Class + mebemoto$Race + mebemoto$Sex + mebemoto$GPA)

summary ( Fmebemoto )
# Step 5
Fmebemoto <- glm ( mebemoto$AvF ~ mebemoto$Major + mebemoto$Overall.EXP + mebemoto$Academic.Class + mebemoto$Race + mebemoto$GPA)

summary ( Fmebemoto )

# Step 6
Fmebemoto <- glm ( mebemoto$AvF ~ mebemoto$Overall.EXP + mebemoto$Academic.Class + mebemoto$Race + mebemoto$GPA)

summary ( Fmebemoto )

# Step 7
Fmebemoto <- glm ( mebemoto$AvF ~ mebemoto$Overall.EXP + mebemoto$Race + mebemoto$GPA)

summary ( Fmebemoto )

# Step 8
Fmebemoto <- glm ( mebemoto$AvF ~ mebemoto$GPA)

summary ( Fmebemoto )

# Step 9
Fmebemoto <- glm ( mebemoto$AvF ~ mebemoto$Overall.EXP)

summary ( Fmebemoto )

### According to backwards deletion none of our performance measures significantly predict future motivation

### Forward
Fmebemoto <- glm ( mebemoto$AvF ~ mebemoto$GPA)

summary ( Fmebemoto )
# Step 2
Fmebemoto <- glm ( mebemoto$AvF ~ mebemoto$Major )
summary ( Fmebemoto )

# Step 3
Fmebemoto <- glm ( mebemoto$AvF ~ mebemoto$Academic.Class )
summary ( Fmebemoto )

# Step 4
Fmebemoto <- glm ( mebemoto$AvF ~ mebemoto$Race )
summary ( Fmebemoto )

# Step 5
Fmebemoto <- glm ( mebemoto$AvF ~ mebemoto$Sex )
summary ( Fmebemoto )

# Step 6
Fmebemoto <- glm ( mebemoto$AvF ~ mebemoto$BST.Score )
summary ( Fmebemoto )

# Step 7
Fmebemoto <- glm ( mebemoto$AvF ~ mebemoto$BST.Class )
summary ( Fmebemoto )

#### Present Motivation Prediction
Pmebemoto <- glm ( mebemoto$AvP ~ mebemoto$Major + mebemoto$Overall.EXP + mebemoto$Academic.Class + mebemoto$Race + mebemoto$Sex + mebemoto$GPA + mebemoto$BST.Score + mebemoto$BST.Class + mebemoto$Overall.EXP.Major: Overall.EXP )
summary ( Pmebemoto )
# Step 2
Pmebemoto <- glm(mebemoto$AvP ~ mebemoto$Major + mebemoto$Overall.EXP + mebemoto$Academic.Class + mebemoto$Race + mebemoto$Sex + mebemoto$GPA + mebemoto$BST.Score + mebemoto$Overall.EXP + mebemoto$Major:mebemoto$Overall.EXP)
summary(Pmebemoto)

# Step 3
Pmebemoto <- glm(mebemoto$AvP ~ mebemoto$Major + mebemoto$Overall.EXP + mebemoto$Academic.Class + mebemoto$Race + mebemoto$Sex + mebemoto$GPA + mebemoto$Overall.EXP + mebemoto$Major:mebemoto$Overall.EXP)
summary(Pmebemoto)

# Step 4
Pmebemoto <- glm(mebemoto$AvP ~ mebemoto$Major + mebemoto$Academic.Class + mebemoto$Race + mebemoto$Sex + mebemoto$GPA + mebemoto$BST.Class + mebemoto$Major:mebemoto$Overall.EXP)
summary(Pmebemoto)

# Step 5
Pmebemoto <- glm(mebemoto$AvP ~ mebemoto$Major + mebemoto$Academic.Class + mebemoto$Race + mebemoto$Sex + mebemoto$GPA + mebemoto$BST.Class)
summary(Pmebemoto)

# Step 6
Pmebemoto <- glm(mebemoto$AvP ~ mebemoto$Major + mebemoto$Academic.Class + mebemoto$Race + mebemoto$Sex + mebemoto$GPA)
summary(Pmebemoto)

# Step 7
Pmebemoto <- glm(mebemoto$AvP ~ mebemoto$Major + mebemoto$Academic.Class + mebemoto$Race + mebemoto$GPA)
summary(Pmebemoto)

# Step 8
Pmebemoto <- glm(mebemoto$AvP ~ mebemoto$Major + mebemoto$Race + mebemoto$GPA)
```r
summary(Pmebemoto)
#step9
Pmebemoto<-glm(mebemoto$AvP ~ mebemoto$Major+mebemoto$GPA)
summary(Pmebemoto)
#step10
Pmebemoto<-glm(mebemoto$AvP ~ mebemoto$Major)
summary(Pmebemoto)
```

## Nothing is predictive of student present motivation for sample in a backward deletion

### Forward chain
```
Pmebemoto<-glm(mebemoto$AvP ~ mebemoto$GPA)
summary(Pmebemoto)
#Step2
Pmebemoto<-glm(mebemoto$AvP ~ mebemoto$Academic.Class)
summary(Pmebemoto)
#Step3
Pmebemoto<-glm(mebemoto$AvP ~ mebemoto$Race)
summary(Pmebemoto)
#Step4
Pmebemoto<-glm(mebemoto$AvP ~ mebemoto$Sex)
summary(Pmebemoto)
#Step5
Pmebemoto<-glm(mebemoto$AvP ~ mebemoto$BST.Score)
summary(Pmebemoto)
#Step6
Pmebemoto<-glm(mebemoto$AvP ~ mebemoto$BST.Class)
summary(Pmebemoto)
#Step7
Pmebemoto<-glm(mebemoto$AvP ~ mebemoto$Overall.EXP)
```
summary (Pmebemoto)

### Nothing Predicts present

#### Self efficacy predictions

SEmbebemoto <- glm (mebemoto$AvSE ~ mebemoto$Major + mebemoto$Overall.EXP + mebemoto$Academic.Class + mebemoto$Race + mebemoto$Sex + mebemoto$GPA + mebemoto$BST.Score + mebemoto$BST.Class + mebemoto$Overall.EXP + mebemoto$Major:mebemoto$Overall.EXP)

summary (SEmbebemoto)

# Step 2

SEmbebemoto <- glm (mebemoto$AvSE ~ mebemoto$Major + mebemoto$Overall.EXP + mebemoto$Academic.Class + mebemoto$Sex + mebemoto$GPA + mebemoto$BST.Score + mebemoto$BST.Class + mebemoto$Overall.EXP + mebemoto$Major:mebemoto$Overall.EXP)

summary (SEmbebemoto)

# Step 3

SEmbebemoto <- glm (mebemoto$AvSE ~ mebemoto$Overall.EXP + mebemoto$Academic.Class + mebemoto$Sex + mebemoto$GPA + mebemoto$BST.Score + mebemoto$BST.Class + mebemoto$Overall.EXP + mebemoto$Major:mebemoto$Overall.EXP)

summary (SEmbebemoto)

# Step 4

SEmbebemoto <- glm (mebemoto$AvSE ~ mebemoto$Overall.EXP + mebemoto$Academic.Class + mebemoto$Sex + mebemoto$GPA + mebemoto$BST.Score + mebemoto$BST.Class)

summary (SEmbebemoto)

# Step 5

SEmbebemoto <- glm (mebemoto$AvSE ~ mebemoto$Overall.EXP + mebemoto$Academic.Class + mebemoto$Sex + mebemoto$GPA + mebemoto$BST.Score)

summary (SEmbebemoto)
```r
# Step 6
SEmebemoto <- glm(mebemoto$AvSE ~ mebemoto$Overall.EXP + mebemoto$Academic.Class + mebemoto$Sex + mebemoto$GPA)
summary(SEmebemoto)

# Step 7
SEmebemoto <- glm(mebemoto$AvSE ~ mebemoto$Overall.EXP + mebemoto$Academic.Class + mebemoto$GPA)
summary(SEmebemoto)

# Step 8
SEmebemoto <- glm(mebemoto$AvSE ~ mebemoto$GPA)
summary(SEmebemoto)

# GPA Predicts Self Efficacy
## Forward Self Efficacy
SEmebemoto <- glm(mebemoto$AvSE ~ mebemoto$GPA + mebemoto$Major)
summary(SEmebemoto)

# Step 2
SEmebemoto <- glm(mebemoto$AvSE ~ mebemoto$GPA + mebemoto$Academic.Class)
summary(SEmebemoto)

# Step 3
SEmebemoto <- glm(mebemoto$AvSE ~ mebemoto$GPA + mebemoto$Race)
summary(SEmebemoto)

# Step 4
SEmebemoto <- glm(mebemoto$AvSE ~ mebemoto$GPA + mebemoto$Sex)
summary(SEmebemoto)

# Step 5
SEmebemoto <- glm(mebemoto$AvSE ~ mebemoto$GPA + mebemoto$BST.Score)
summary(SEmebemoto)
```
# Step 6
SEmebemoto <- glm ( mebemoto$AvSE ~ mebemoto$GPA + mebemoto$BST.Class )
summary ( SEmebemoto )

# Step 7
SEmebemoto <- glm ( mebemoto$AvSE ~ mebemoto$GPA + mebemoto$Overall.EXP )
summary ( SEmebemoto )

#### SE explained by GPA

### Motivational Predictors of each other

## SE
SEmebemoto <- glm ( mebemoto$AvSE ~ mebemoto$GPA + mebemoto$AvE + mebemoto$AvF + mebemoto$AvP )
summary ( SEmebemoto )

## Step 2
SEmebemoto <- glm ( mebemoto$AvSE ~ mebemoto$GPA + mebemoto$AvE + mebemoto$AvP )
summary ( SEmebemoto )

## Step 3
SEmebemoto <- glm ( mebemoto$AvSE ~ mebemoto$AvE + mebemoto$AvP )
summary ( SEmebemoto )

#### Self-Efficacy is best predicted by expectancy and Present

### Present with affectors
Pmebemoto <- glm ( mebemoto$AvP ~ mebemoto$GPA + mebemoto$AvE + mebemoto$AvF + mebemoto$AvSE )
summary ( Pmebemoto )

# Step 2
Pmebemoto <- glm ( mebemoto$AvP ~ mebemoto$AvE + mebemoto$AvF + mebemoto$AvSE )
summary ( Pmebemoto )
Future with affect

\[ \text{Fmebemoto} \leftarrow \text{glm} \left( \text{mebemoto}\$AvF \sim \text{mebemoto}\$GPA + \text{mebemoto}\$AvE + \text{mebemoto}\$AvP + \text{mebemoto}\$AvSE \right) \]

\text{summary (Fmebemoto)}

# Step 2

\[ \text{Fmebemoto} \leftarrow \text{glm} \left( \text{mebemoto}\$AvF \sim \text{mebemoto}\$AvE + \text{mebemoto}\$AvP + \text{mebemoto}\$AvSE \right) \]

\text{summary (Fmebemoto)}

# Step 3

\[ \text{Fmebemoto} \leftarrow \text{glm} \left( \text{mebemoto}\$AvF \sim \text{mebemoto}\$AvE + \text{mebemoto}\$AvP \right) \]

\text{summary (Fmebemoto)}

# Step 4

\[ \text{Fmebemoto} \leftarrow \text{glm} \left( \text{mebemoto}\$AvF \sim \text{mebemoto}\$AvP \right) \]

\text{summary (Fmebemoto)}

Expectancy with affect

\[ \text{Emebemoto} \leftarrow \text{glm} \left( \text{mebemoto}\$AvE \sim \text{mebemoto}\$GPA + \text{mebemoto}\$AvP + \text{mebemoto}\$AvF + \text{mebemoto}\$AvSE \right) \]

\text{summary (Emebemoto)}

# Step 2

\[ \text{Emebemoto} \leftarrow \text{glm} \left( \text{mebemoto}\$AvE \sim \text{mebemoto}\$GPA + \text{mebemoto}\$AvP + \text{mebemoto}\$AvSE \right) \]

\text{summary (Emebemoto)}

Determining % of Variance explained by items in models:

Performance Only Models

SE

\[ \text{SEmebemoto} \leftarrow \text{glm} \left( \text{mebemoto}\$AvSE \sim \text{mebemoto}\$GPA \right) \]

\text{summary (SEmebemoto)}

\text{Rsquare Adj (SEmebemoto)}
## Performance and Affect Models

### E

Emebemoto <- glm ( mebemoto$AvE ~ mebemoto$GPA)

summary ( Emebemoto )

Rsquare Adj ( Emebemoto )

### F

Fmebemoto <- glm ( mebemoto$AvF ~ mebemoto$AvP)

summary ( Fmebemoto )

Rsquare Adj ( Fmebemoto )

### Se

SEmebemoto <- glm ( mebemoto$AvSE ~ mebemoto$AvE+mebemoto$AvP)

summary ( SEmebemoto )

Rsquare Adj ( SEmebemoto )

# Variable Predictor Weight

Emebemoto <- glm ( mebemoto$AvE ~ mebemoto$AvSE)

summary ( Emebemoto )

Rsquare Adj ( Emebemoto )

Emebemoto <- glm ( mebemoto$AvE ~ mebemoto$AvSE+mebemoto$GPA)

summary ( Emebemoto )

Rsquare Adj ( Emebemoto )

Emebemoto <- glm ( mebemoto$AvE ~ mebemoto$AvSE+mebemoto$GPA)

summary ( Emebemoto )

Rsquare Adj ( Emebemoto )

Emebemoto <- glm ( mebemoto$AvE ~ mebemoto$AvP+mebemoto$AvSE+mebemoto$GPA)

summary ( Emebemoto )

Rsquare Adj ( Emebemoto )

### Se

SEmebemoto <- glm ( mebemoto$AvSE ~ mebemoto$AvE+mebemoto$AvP)

summary ( SEmebemoto )

Rsquare Adj ( SEmebemoto )

# Variable Predictor Weight

SEmebemoto <- glm ( mebemoto$AvSE ~ mebemoto$AvE)
summary (SEmebemoto)
RsquareAdj (SEmebemoto)

##P
Pmebemoto <- glm (mebemoto$AvP ~ mebemoto$AvE + mebemoto$AvF + mebemoto$AvSE)
summary (Pmebemoto)
RsquareAdj (Pmebemoto)

#Variable Predictor Weight
Pmebemoto <- glm (mebemoto$AvP ~ mebemoto$AvF)
summary (Pmebemoto)
RsquareAdj (Pmebemoto)
Pmebemoto <- glm (mebemoto$AvP ~ mebemoto$AvF + mebemoto$AvSE)
summary (Pmebemoto)
RsquareAdj (Pmebemoto)
Cluster Analysis for Sophomore Engineering Students

##### Loading of ME BE only data set
`mebemoto` <- read.csv("~/Dropbox/Student Motivation and Learning Research/Adams work/Student Motivation and Learning Survey/Adam Analysis/Linear Models for Sampling/201_Responses_Correct Factors_Overall EXP_ME BE only.csv", sep=";")
View(mebemoto)

# subsetting the data
Moto<-'mebemoto[,c(29:32)]
View(Moto)

Motos<-'scale(Moto)
## Partitioning
# determine the number of clusters
wss<-(nrow(Motos)-1)*sum(apply(Motos,2,var))
for (i in 2:15) wss[i]<-sum(kmeans(Motos,centers=i)$withinss)
plot(1:15, wss, type="b", xlab="Number of Clusters", ylab="Within groups sum of squares", main="Plot to Determine the Necessary Number of Clusters")

# K-means Cluster Analysis
fit<-'kmeans(Moto, 4) #4 result of cluster solution
#get cluster means
aggregate(Moto, by=list(fit$cluster), FUN=mean)
Moto4<-'data.frame(Moto, fit$cluster)
View(Moto4)

mebemoto<-'data.frame(mebemoto, fit$cluster)
View(mebemoto)

### Plotting Solution
clusplot(Moto, fit$cluster, color=TRUE, shade=TRUE, labels=2, lines=0)

# Centroid plot
plotcluster(Moto, fit$cluster)

GPA<-mebemoto[,c(12)]

# K-means Cluster Analysis
fit2<-kmeans(Moto, 6) # 5 result of cluster solution
# get cluster means
aggregate(Moto, by=list(fit2$cluster), FUN=mean)
Moto6<-data.frame(Moto, fit2$cluster)
View(Moto6)

### Plotting Solution
clusplot(Moto6, fit2$cluster, color=TRUE, shade=TRUE, labels=2, lines=0)

# Centroid plot
plotcluster(Moto, fit2$cluster)

# Cluster Validation ## not working, no clue how to make the distance matrix between objects
cluster.stats(dmat, fit$cluster, fit2$cluster)

dmat<-dist(fit$cluster)

# model Based clustering
fit<-Mclust(Moto, G=NULL, modelNames=NULL, prior=NULL, control=emControl()
        , initialization=NULL, warn=FALSE)
plot(fit, Moto)
print(fit)

### More robust cluster analysis, partitioning method
pamk(Moto, krange = 2:10, criterion = "asw", usepam = TRUE, scaling = TRUE,
     alpha = 0.05, critout = TRUE)

### GPA Means of the 4 groups
Group1 <- subset(mebeMoto, fit.cluster == 1)
View(Group1)
mG1 <- mean(Group1[,c(12)])
View(mG1)

Group2 <- subset(mebeMoto, fit.cluster == 2)
View(Group2)
mG2 <- mean(Group2[,c(12)])
View(mG2)

Group3 <- subset(mebeMoto, fit.cluster == 3)
View(Group3)
mG3 <- mean(Group3[,c(12)])
View(mG3)

Group4 <- subset(mebeMoto, fit.cluster == 4)
View(Group4)
mG4 <- mean(Group4[,c(12)])
View(mG4)

epress<-mebemoto[,c(29:32)]
rownames(epress)<-mebemoto$ID
internal<-clValid(epress,2:6,clMethods=c("kmeans","diana","fanny","som","pam","sota","clara","model"),validation="internal")
summary(internal)

op<-par(no.readonly=TRUE)
plot(internal)

stab<-clValid(epress,2:6,clMethods=c("kmeans","diana","fanny","som","pam","sota","clara","model"),validation="stability")
summary(stab)
plot(stab)

## sorting MEBEmoto by cluster
View(mebemoto)
smebemoto<-mebemoto[order(fit$cluster),]
View(smebemoto)
Appendix D

Interview Protocol

Long-Term Goals:

• What are your goals for the future?
  – What are your personal goals for the future?
  – What are your career goals for the future?
  – Describe where you see yourself in 10 years?
  – Can you think of anything that could make you change your goals?

• What would you ideally like to be in the future?
  – If you could pick one thing and it could happen what would it be?
  – If you could pick a professional goal to attain what would it be?

• What do you think you can be in the future?
  – What are you actively striving for?
  – What goals are you currently pursuing to reach this future?

• What do you not want to be in the future?
  – In other words, what jobs, or careers do you know you do not want to pursue?

• Why are you pursuing an engineering degree?
• How long do you plan on remaining in an engineering related profession after graduation?
  – How long after graduation do you plan on using technical information as part of your day to day work?

• What parts of your education do you see as relevant to your future?
  – What skills are relevant to ideal self (who you would ideally like to be)?
  – What skills are relevant to who you think you could be?
  – What parts of your education do you see as not relevant to your future?

• How do you see your education playing into your career?

• What skills do you view as important for your profession?
  – What kind of profession (if more than 1 profession mentioned)?

• How did you develop these conceptions of your future?

  **Short-Term Tasks/Goals:**

• What is an engineering problem?
  – What is an engineering problem in your classes?
  – If you were write a problem, what would you want an engineering problem to look like?

• Describe an engineering problem that would be beneficial to you in your engineering education.
  – What features of this problem make it an ideal problem?
  – For example well defined v ill defined, single v multiple answer

• Have you encountered any of these problems while pursuing your degree?
  – If yes, please describe in what context and what it looked like.
  – If no, please describe where your ideal problem could fit into your degree.

• Why do you solve engineering problems?

• Do you encounter problems that must be solved in your non-engineering classes?
  – Should we be asking: What types of problems do you solve in your non-engineering classes?
– Why do you solve these problems?
– Do you approach, solve, or work on these problems any differently than your engineering problems?
– How?, In what ways?

• What if anything do you hope to get from solving engineering problems?

• Given a problem you have seen in the past:
  – What are your thoughts of this problem?
  – What problem features are you focusing on?
  – What aspects of the problem are important to you?
  – How does this problem compare with your ideal problem?
  – Why would you want to solve this problem

• How important are grades?
  – Why are grades important to you?

**Interconnection of Long- and Short-Term:**

• How do the problems you solve relate to your future goals?
  – In engineering courses
  – In co-op/intern
  – In research experiences

• How do your future goals affect how you approach the problems you solve?

• How do you future goals affect your actions with respect to your courses?

• What do you do when you fail achieving your goal in engineering?
  – What do you define failure as?
  – What do when you struggle to get to an answer?

• How do you define success?
− What do you consider success for a task?

**How did you get here:**

- What level of engineering are you in now?
- Why did you pursue your current engineering degree?
- What made you select engineering?
- What experiences do you have outside of the classroom related to engineering, in other words co-op, internship, research, creative inquiry, etc.?
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