Longitudinal Study of Changes in Student Motivation and Attitudes in Engineering

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Introduction

This research study focuses on assessing student motivations and attitudes towards engineering and their future in engineering at multiple time points to track changes in motivational attributes over time. Motivation has been linked to many aspects of student performance and behavior[1-5]. More recently and specifically, these studies have extended to engineering education[6-13]. Through a longitudinal study of engineering students at a southeastern land grant university, we seek to answer the following research question: How do motivational attributes change over time for students majoring in engineering?

Background and Theoretical Frameworks

<u>Connections between Motivation and Learning</u>
Social cognitive theories[14] recognize the link between learning and motivation, as well as our understanding of motivation as dynamic and multi-faceted[15]. According to these theories, motivation is not a static attribute, as a student's motivation changes over time, situation and context. Students' perceptions of themselves as potential engineers also change during their college experience, and these perceptions are related to aspects of motivation, such as their value beliefs, their beliefs about their own competencies, and their choice to persist in engineering in college[6].

<u>Expectancy Value Theory</u>
Achievement motivation, which encompasses students' attitudes about their abilities and tasks, can elucidate student choices related to persistence in engineering, solving problems, and the value of tasks encountered in an engineering environment[16]. Achievement motivation serves as a useful framework for the examination of research questions related to students' attitudes about pursuing engineering, and how these factors affect students' learning experiences. For this work, we apply Expectancy Value models of motivation[17], in particular a model developed by Eccles et al.[18], which posits that expectations of success and the value placed on success determine motivation to achieve, and directly influence performance, persistence, and task choice. Expectancy of success is defined as one's beliefs about competence in a domain; it is not necessarily task-specific. Students' expectancy is based partly on their self-efficacy[14] in addition to their perceptions about the difficulty of the goal, their prior experience, and peer encouragement from others[19]. Students with high self-efficacy use more cognitive and metacognitive strategies as well as self-regulatory strategies such as planning, monitoring, and regulating[20].

<u>Future Time Perspective</u>
Future Time Perspective (FTP) theory takes into account aspects of achievement motivation that pertain to students' perceptions of the time dimension of tasks and goals[21-23]. FTP integrates

perceptions about the future into present task completion and motivational goal setting. FTP provides insight into students' perceived instrumentality for completing a specific task[24-25]. Perceived instrumentality is the perception of the importance of a task to achieve one's goals, either in terms of one's long-term goals[26], or to more proximal goals such as classroom performance[27]. Perceived instrumentality is a situational, context-dependent aspect of FTP theory that accounts for the motivation of students to complete academic goals[28]. Perceived instrumentality can be considered to have both intrinsic (endogenous) and extrinsic (exogenous) attributes[29]. Perceived instrumentality has been empirically distinguished from other value-related attributes of achievement motivation, and is predictive of course performance[27]. Aspects of perceived instrumentality capture how students perceive the importance of what they are doing in class relative to their future careers[24, 26, 30].

Goal Orientation

Goal orientation research typically focuses on attitudes about short-term goals. There are three primary ways in which goal orientation is characterized in the literature. The first is mastery approach, in which the main purpose for learning and achieving is to gain knowledge and understanding[1]. The second is performance approach, in which learners are driven by positive affirmation from others[20]. The third, work avoid, is characterized by a desire to put in as little effort as possible and to avoid tasks that are perceived to be difficult[31]. While mastery and performance approach goal orientations have been correlated to positive outcomes such as increased expectancy and performance[31], work avoid orientation has been linked to low academic outcomes[32].

Metacognition

We hypothesize that students' metacognition strategy use will be important in connecting student motivation and engineering problem solving skills. Metacognitive strategies facilitate organization and monitoring, thus are key to successful problem solving[33].Metacognition has two main aspects: knowledge of cognition, which includes declarative knowledge, procedural knowledge, and conditional knowledge[34], and regulation of cognition, which includes planning, information management strategies, comprehension monitoring, debugging strategies, and evaluation. Metacognition was assessed in this work in terms of students' perceptions of their use of metacognitive strategies when solving an engineering problem. These factors will serve as outcome variables for future studies.

Methods

Motivation and Attitudes in Engineering (MAE) Survey

Our research group has constructed and tested a quantitative instrument, the Motivation and Attitudes in Engineering (MAE) survey, which categorizes undergraduate engineering students based on their future time perspectives (FTPs), or their future goals and how those goals affect actions in the present[10, 11, 35]. The items were adapted from pre-existing surveys, FTP literature, and findings from the qualitative analysis. Items related to these three goal orientations were added to the survey based on the analysis of interview data[36].

The validity and reliability of the MAE survey was tested and the survey was found to have acceptable reliability with first and second year engineering students (item reliability (R^2) was greater than 0.50, construct reliability was greater than 0.70, and average variance extracted was greater than 0.50). Survey factors included: Performance Approach, Mastery Approach, Work Avoid, Expectancy, Perceptions of the Future, Perceived Instrumentality, and Metacognition, which includes both knowledge of cognition and regulation of cognition. A full description of how these items were developed and adapted from other sources is provided in our previous work[10], and a summary of the meaning of each factor is shown in Table 1 below. While the survey has evolved throughout the testing process, a subset of items within each category were on all versions of the survey that are included in this study. Survey responses in Fall 2013 and Fall 2014 were on a five point anchored scale 1="Strongly Disagree" and 5= "Strongly Agree." The Spring 2016 survey was updated to use a seven point anchored scale. The five-point Likert scale was adjusted to the seven-point Likert scale for comparison of the data across time points.

Data Collection

The MAE survey was distributed in Fall 2013 to first-year engineering students, early in students' first semester of college (n=984), and again in Fall 2014 to second year engineering students in a variety of sophomore level engineering courses (n=657; for example, a materials engineering course for non-majors). The students who completed the survey in Fall 2013 were not specifically targeted in Fall 2014. Students who completed the survey in Fall 2013 and Fall 2014 were invited to complete it again in Spring 2016. Only 12 of these participants in 2014 had taken the survey in 2013; therefore, there are data for each student at two time points, either 2013 and 2016 (n=115) or 2014 and 2016 (n=132).

Table 1: Description of the factors measured in the MAE survey, their abbreviations and definitions of what a high score in this factor indicates.

Factor Name	Definition
Performance Approach	The student's academic goals include wanting to receive favorable evaluation on tasks compared to their peers.
Mastery Approach	The student's academic goals include wanting to master, or learn the concepts, on tasks.
Work Avoid	The student's academic goals include wanting to complete the task with as little effort as possible.
Expectancy	The student believes they are competent at their engineering coursework.
Perceptions of the Future	The student is certain about being an engineer.
Perceived Instrumentality	The student perceives their engineering coursework to be important to achieving their future goals.
Metacognitive Strategies	The student believes they use specific metacognitive strategies of knowledge and regulation.

Statistical Analysis and Modeling

Survey data for students who responded in both Fall 2013 and Spring 2016 (n=115) and those who responded in both Fall 2014 and Spring 2016 (n=133) were paired. Changes in motivation and metacognition over time (from 2013 to 2016 and from 2014 to 2016) were analyzed.

The statistical programming language R[37] was used for data analyses and to generate plots. Data from 2013, 2014, and 2016 were considered to examine changes in each factor (Performance Approach, Mastery Approach, Work Avoid, Expectancy, Perceptions of the Future, Perceived Instrumentality, and Metacognition) over time. We identified outlying observations within each variable as those observations that were three or more interquartile ranges away from the first and third quartiles. We checked for normality using Shapiro-Wilks test. Matched pairs t-tests were used to compare changes from 2013 to 2016, and from 2014 to 2016, for each factor due to the dependent measurements on individuals in these years. When the assumption of normality was not satisfied, we used Wilcoxon Signed-Rank test to make these comparisons. Some students did not answer every question on the survey, therefore the numbers included in each comparison are different for each factor. A significance level of 0.05 was used for all tests. P-values were adjusted using a Bonferroni correction because two multiple comparisons were conducted for each factor (comparing 2013 to 2016 and 2014 to 2016). For each t-test, the effect size, Cohen's *d*, was computed[38] as a standardized way of examining the differences between the groups that takes into account the standard deviation[39].

Results and Discussion

Results of the statistical analyses are compiled in Table 2. Significant decreases ($p<0.0005$) were observed for Perceived Instrumentality from 2013 to 2016 and from 2014 to 2016, with medium to large effect sizes[39] of 0.52 and 0.79, respectively. Significant decreases ($p<0.05$) were observed for Mastery Approach and Expectancy 2013 to 2016 and from 2014 to 2016, with low to medium effect sizes[39] (ranging from 0.22 to 0. 46). The average change in Perception of the Future significantly decreased from 2013 to 2016 ($p=0.0005$) with a small effect size[39]. The average Perception of Future score did not significantly change from 2014 to 2016. No significant changes were observed for Metacognition for either comparison.

Significant decreases with low to medium effect sizes in average Performance Approach and Mastery Approach goal orientation scores were evident between 2014 and 2016, and for Mastery Approach between 2013 and 2016. This is of concern to educators because both mastery and performance goal orientations have been linked to motivation, strategy use, and performance[31]. No significant changes were observed for Work Avoid in either comparison.

It is interesting to observe significant decreases in Expectancy between both 2013 and 2016 and between 2014 and 2016, with a medium effect size for the decrease between 2014 and 2016. Student perceptions about their abilities to complete tasks in their engineering courses appear to decrease after their first year, possibly due to the challenges of upper level courses with which they are confronted.

Table 2: Summary of mean (standard deviation) values for all factors for each year and the matched pairs t-test or Signed-Rank test results for comparisons, including the test statistic *t(n-1)* or *S*, respectively, the sample size *n*, the p-value, and the effect size *d* for significant results. Factor scores are on a scale from 1 ("Strongly Disagree") to 7 ("Strongly Agree").

Factor Name	2013 Mean (SD); n	2014 Mean (SD); n	2016 Mean (SD); n	2013-2016 Comparison	2014-2016 Comparison
Performance Approach	4.56 (1.13); n=112	4.77 (1.36); n=133	4.33 (1.26); n=229	t(110) = -1.76 p=0.161	**t(132) = -2.42 p=0.034; *d*=0.24
Mastery Approach	6.34 (0.92); n=115	6.56 (0.67); n=133	6.10 (1.04); n=229	**S=-1065.50 p=0.003; *d*=0.29	***S=-1564.00 p<0.001; *d*=0.46
Work Avoid	3.61 (1.50); n=115	3.36 (1.53); n=132	3.47 (1.42); n=229	t(114) = -0.34 p=1.000	t(131) = 0.06 p=1.000
Expectancy	5.31 (1.19); n=114	5.73 (0.98); n=131	4.99 (1.36); n=227	**t(112) = -2.38 *p*=0.038; *d*=0.29	***t(128) = -5.26 *p*<0.001; *d*=0.54
Perceptions of the Future	5.63 (1.17); n=114	5.28 (1.07); n=131	5.32 (1.13); n=226	**t(109) = -2.99 *p*=0.007; *d*=0.33	S=799.5 *p*=0.114
Perceived Instrumentality	5.66 (1.17); n=115	6.08 (0.90); n=132	5.12 (1.28); n=227	***t(113) = -4.17 *p*<0.001; *d*=0.52	***t(130) = -7.71 *p*<0.001; *d*=0.79
Metacognitive Strategies	5.15 (0.86); n=111	5.20 (0.85); n=130	5.12 (0.76); n=227	t(109) = -1.10 *p*=0.544	t(128) = -0.46 *p*=1.000

* significant at α=0.1;** significant at α=0.05; *** significant at α=0.001

In terms of FTP, a decrease was observed in Perceptions of the Future between 2013 and 2016, with low effect size, but not between 2014 and 2016. The underlying reasons for the decrease in students' Perceptions of the Future in engineering cannot be confirmed with the quantitative data alone. However, one possibility is that as students' progress forward in time from their first year in an engineering major, they move from a limited understanding of what it means to be an engineer to more well-developed future goals, and may have more negative views of their future in engineering as they understand more clearly what it entails. The significant decreases in Perceived Instrumentality, with medium to large effect sizes, indicate that students find their courses less useful in terms of meeting their future goals. Together with a decrease in Perceptions of the Future, these overall decreases in FTP factors indicate that students in this engineering program are less motivated in terms of future goals and how they are achieving them as they progress through their major.

Conclusions and Implications for Practice

In this study, changes in engineering students' motivational attributes and attitudes about their future in engineering were shown to change over time through a comparison of two sets of survey data collected about 2.5 years apart, starting with data collected in the students' first year in an engineering program. While it has been demonstrated that motivations are not static and change with experience and knowledge, in our population, motivations related to the future in engineering actually decreased over the course of the students' experience in engineering majors. A possible way to counteract such decreases is for students to receive specific messages about what they are likely to be doing in the future as engineers (or as graduates of engineering programs), and how their present activities and tasks can help them reach their future goals. Increasing student motivation in engineering can in turn positively affect student learning.

Limitations and Future Work

Measures of student perceptions of metacognition are self-reported, and are therefore not reliable as the sole indication of the extent to which students are applying metacognitive strategies. In a separate study, we have collected evidence of students' metacognitive strategies through reflective journals[40] and interviews[41,42]. Relationships between self-reported and actual metacognitive strategies will be examined in future studies.

An important learning outcome in engineering education is problem solving. Survey items related to students' problem solving self-efficacy are being tested and analyzed along with evidence of students' actual problem solving practices through a multi-phase, multi-institution, mixed methods study that is currently underway in our research group.

We will be analyzing student persistence data for those who completed the MAE survey as first year students in 2013 by creating a logistic regression model to determine which, if any, of the motivation factors in our study are predictive of student retention in an engineering major[43]. We selected data from students who completed the survey in Fall 2013 to capture as long a period of time as possible, and because the largest number of students completed the survey during that semester. We will determine FTP factor means and use students' current major as the outcome variable (engineering vs. non-engineering majors, and STEM vs. non-STEM majors) for the logistic regression model.

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