122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Paper ID #12212

Changes in Motivational Beliefs Among First-year Engineering Students: Relations to Academic Achievement and Retention Status

Ms. Yu-Yun Liu, University of Louisville

Yu-Yun Liu is a doctoral candidate in the Department of Educational and Counseling Psychology, Counseling, and College Student Personnel at the University of Louisville. Her research interests include motivational beliefs, achievement, and college student mental health issues.

Dr. Kate E. Snyder, University of Louisville

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Abstract

Expectancy-value theory has long been used to explain students' academic choices and achievement. Expectations for success and subjective task values are two main components of expectancy-value theory. We focused on three components of subjective task value in the current study: judgments of interest in a domain (*interest*), judgments of the domain's meaningfulness or consistency with one's identity (*attainment value*), and anticipated affective drawbacks of engaging in a domain (*perceived psychological cost value*). Research is needed to examine if and how perceived task value for engineering changes over time and whether those changes influence both achievement and retention in engineering. We hypothesized that increases in interest and attainment value, and decreases in perceived psychological cost value, would be associated with higher academic achievement among undergraduates in engineering and with retention (maintaining enrollment in the college of engineering the following year).

Participants in the current study included first-year students from an urban metropolitan university enrolled in a school of engineering (n = 376, 21.8% female) in Fall 2013. Participants completed a self-report survey assessing their motivational beliefs twice during the first semester (Time 1 [T1]: first week of the semester; Time 2 [T2]: thirteenth week of the semester). Interest in engineering was measured by a single item. A five-item scale was used to measure attainment value (AV; internal consistency: α_{T1} = .84, α_{T2} = .91; sample item: "It is important for me to be a person who reasons like an engineer."). A four-item scale was used to measure one component of perceived cost value: *psychological* cost value (PCV; internal consistency: α_{T1} = .61, α_{T2}= .70; sample item: "I am concerned that I won't be able to handle the stress that might go along with my engineering major."). Academic achievement was measured by first semester overall GPA.

A linear regression was conducted to determine if changes in motivational beliefs predicted academic achievement after controlling for general academic ability (ACT composite score). Change scores were calculated for each of the three independent variables by subtracting Time 2 values from Time 1 values. Standardized coefficients represent the association of each independent variable with GPA. Results suggested that *changes* in these beliefs (interest, attainment value, and perceived psychological cost value) were statistically significantly associated with student academic achievement, consistent with our hypotheses. Specifically, increases in interest in engineering and attainment value for engineering were associated with higher GPA. In contrast, a *decrease* in perceived psychological cost value (i.e., worrying less about what it means to do poorly in engineering) was associated with higher GPA. We conducted a logistic regression to examine how changes in these task values predicted retention status the following year. After controlling for academic ability (ACT composite score), changes in interest significantly predicted one-year retention status of the participating engineering students.

Purpose

Limited empirical evidence exists on why students choose to enter and remain in the field of engineering[1]. In addition, most research has focused on high school students' interests towards

engineering before they entered college, instead of investigating interest in engineering among college students enrolled in colleges of engineering [2]. Competency beliefs are studied more widely than value beliefs; however, the relation between value beliefs and academic achievement and retention status among freshman engineering students is still relatively unexamined empirically.

Literature Review

Expectancy-value theory has been used to understand students' achievement motivation and how they make academic decisions[3]. Expectations for success and subjective task values are two main components of expectancy-value theory. Theoretically, subjective task values influence how individuals perceive tasks or domains and how individuals then determine whether or not to persist in a domain[4,5,6]. However, limited research has focused on how subjective task values relate to choices and persistence in STEM(e.g., choosing to major in STEM-related fields)[1]. Among the few studies that looked at the factors of persistence in the STEM fields, subjective task value stood out as one predictive factor[7,8].

Subjective task value consists of four elements[3,5,6]: interest, attainment value, utility value, and cost value. In this current study, we chose to focus on three of these: interest, attainment value, and one aspect of perceived cost value that may be especially relevant for engineering students (psychological cost value). Intrinsic value, often associated greatly with enjoyment of doing an activity or task, is quite conceptually similar with interest[4,6]. Interest is a motivational variable that is related to academic achievement[9,10]. Attainment value is the perceived importance and meaningfulness of doing a task; it may also be described as someone's perception of how engaging in a task or domain is consistent with one's identity[4,6]. Perceived cost value is associated with evaluating the prices of success or failure when engaging in a task[4,6]. Little is known on the impact of perceived cost, mainly because it has been infrequently measured[11,12]. Studies that included the variable of perceived cost often found the relationship between subject task values and academic outcomes to be inversely related[12,13]. In the current study, we examine *psychological* cost value, which is one component of perceived cost value. Psychological cost value refers to the affective or emotional drawbacks of engaging in a domain, such as the emotional price of failing or the perceived level of stress associated with engagement[13].

Improving student retention in STEM in general has elicited considerable research attention[12,14]. Subjective task values are critical in helping retain students in the fields of engineering, physical and IT-related sciences[12,15].Helping students connect their personal identities to engineering identities can increase persistence in STEM fields[1].Prior research finds that interest is a predictor of retention, especially among first-year engineering students[14,16].In one recent study, researchers examined gender disparities in expressed interest toward engineering related fields and its relationship with ACT mathematics scores over the past 30 years[2]. Despite the obvious gender disparity in enrollment and expressed interest, the interest patterns for both male and female students were similar across almost all the disciplines. In addition, students also reported that the lack of preparation for the academic work STEM fields, as evidenced by their low ACT mathematics scores, often led to poor performance in STEM fields. When looking at students' achievement and retention status in the engineering fields, interest and academic readiness appear to be important predictors of later academic performance.

In summary, subjective task value has been found to relate positively to both academic achievement and retention in STEM fields. However, no known research has focused on examining how *changes* in these value beliefs might relate to students' academic achievement and their retention status, particularly in engineering. The purpose of this study is to expand upon prior research by examining how *changes* in key facets of subjective task value, not just absolute levels, are associated with achievement and persistence in engineering at the undergraduate level.

Research Questions

Prior research finds that subjective task values are positively correlated with academic achievement and retention of students in STEM fields, especially for first-year engineering students. It remains unclear whether changes in these subjective task values are also related to academic achievement and retention. The purpose of the current study is to examine if changes in interest, attainment value, and psychological cost value predict academic achievement and one-year retention status for first-year engineering students.

RQ. 1 Do changes in interest, attainment value, and psychological cost value predict academic achievement among freshman engineering students above and beyond general academic ability (ACT composite score)?

RQ. 2 Do changes in interest, attainment value, and psychological cost value predict students' one-year retention status in engineering above and beyond general academic ability (ACT composite score)?

Method

Participants

In the fall semester of 2013, all 505 students in the freshman cohort in the engineering school were invited to complete a self-report survey at the beginning and end of the semester. Of those, 496 participated at T1 and 456 participated at T2. Students who did not complete both surveys and students who did not respond to all the questions related to subjective task values were excluded in the data analysis. The final sample included 376 students (21.8% female). The sample was primarily White (88%).The gender composition for our current sample and overall cohort is relatively comparable to national averages, but our sample and cohort has a greater proportion of White students than the racial/ethnic composition of engineering students nationwide[17].

Procedure

All freshman students in the engineering school were recruited through a required course, *Introduction to Engineering*. They received an email with an online survey link from the Office of Institutional Effectiveness and voluntarily completed the survey at the first week (T1) and the 13th week (T2) of the Fall 2013 semester. Instructors for each section of *Introduction to Engineering* also encouraged students to participate in the study. Students were given time in class to complete the survey.

Measures

Interest in engineering. Interest in engineering was measured by a single item with a five-point Likert-scale: "Which of the following statements best describes your interest in engineering?" Responses ranged from 1 (*very low interest – I'm not interested in engineering; I chose engineering for reasons other than interest*) to 5 (*very high interest – I am so interested in engineering that I could not imagine myself studying anything else*). Interest level change was calculated by subtracting each students' Time 1 response from their Time 2response. Positive values indicate an increase in interest, negative values indicate a decrease, and a zero indicates no change in interest.

Attainment Value. A five-item scale of attainment value (AV) was adapted from the Math and Science Partnership – Motivation Assessment Program[18]. Items are rated on a 5-point Likert scale, ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). A sample item reads, "It is important for me to be a person who reasons like an engineer." The scale score for AV was calculated by averaging all five items (internal consistency: $\alpha_{T1} = .84$, $\alpha_{T2} = .91$). Change scores were calculated using the same method as for interest.

Perceived Psychological Cost Value. A four-item scale of effort cost was used to measure perceived psychological cost value[12]. Items are rated on a 5-point Likert scale, ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). A sample item reads, "I am concerned that I won't be able to handle the stress that might go along with my engineering major."Scale scores for perceived psychological cost value were calculated by averaging the four items (internal consistency: $\alpha_{T1} = .61$, $\alpha_{T2} = .70$).

Analyses

All analyses in the current study were conducted using SPSS 22. First, a hierarchical multiple linear regression was conducted to examine if changes in motivational beliefs were related to academic achievement. The dependent variable, academic achievement, was measured by first semester overall GPA. ACT composite score was included as a control variable in the first block of the regression, and all independent variables (change scores for interest, attainment value, and psychological cost value) were added in block two. Next, a logistic regression was conducted to examine whether changes in task values predicted retention status after the first year. Similar to the linear regression analysis, all independent variables in the logistic regression analysis were entered while controlling for ACT composite score.

Results

Descriptive Statistics

Descriptive data (means and standard deviations for interest, attainment value, psychological cost value, and change scores for all three task values) are presented in Table 1. Fall 2013 GPA was statistically significantly correlated, albeit modestly, with changes in all three task values: change in interest ($r = .15$, $p < .01$), change in attainment value ($r = .13$, $p < .05$), and change in perceived psychological cost value ($r = -.14$, $p < .01$). All correlations were in the hypothesized direction. Overall GPA was also statistically significantly correlated with ACT composite score ($r = .41$, $p < .01$).Using Spearman's correlation, one-year retention status (0 = *not retained in engineering*, 1 = *retained in engineering*) was significantly correlated with two components of task value: interest level change ($r = .22$, $p < .01$) and change in attainment value ($r = .20$, $p < .01$).

Table 1
Descriptive Statistics for All Variables (*n* = 376)

	Mean	SD
Fall 2013 overall GPA	2.97	.71
ACT composite score	28.51	3.15
T1: Interest in engineering	4.05	.61
T2: Interest in engineering	3.93	.94
T1: MSPMAP_AV	3.95	.59
T2: MSPMAP_AV	3.76	.80
T1: MSPMAP_PCV	3.29	.75
T2: MSPMAP_PCV	3.26	.81
Change in interest	-.12	.80
Change in attainment value	-.19	.67
Change in perceived psychological cost value	-.04	.72

Regression

To understand the association between changes in motivational beliefs and students' academic achievement, we conducted a hierarchical multiple linear regression analysis (Table 2). First, an analysis with ACT composite score as the only independent variable was conducted (Model 1), and ACT composite score was a statistically significant predictor of Fall 2013 overall GPA, $F(1, 374) = 75.423$, $p < .01$, $R^2 = .168$. The full model with ACT composite score and changes in task values (interest, attainment value, and perceived psychological cost value) significantly predicted students' first semester overall GPA, $F(4,371) = 26.969$, $p < .01$, $R^2 = .225$. There were also significant main effects on overall GPA; ACT composite score ($\beta = .404$, $t = 8.82$, $p < .001$), interest level change ($\beta = .128$, $t = 2.68$, $p = .008$), change in AV ($\beta = .130$, $t = 2.604$, $p = .010$), and change in PCV ($\beta = -.178$, $t = -3.712$, $p < .001$).

Table 2
Linear Regression Analyzing the Association of Changes in Task Value with Academic Achievement controlling for ACT composite (N=376)

Variable	*b (SE)*	*β*	*p*
Model 1			
ACT composite score	.093 (.011)	.410	.000
Model 2			
ACT composite score	.091 (.010)	.404	.000
Interest level change	.114 (.043)	.128	.008
Change in attainment value	.137 (.053)	.130	.010
Change in perceived psychological cost value	-.176 (.048)	-.178	.000

A logistic regression was also performed to determine the association between changes in motivational beliefs and one-year engineering retention status (Table 3). The test against an ACT composite score only model was statistically significant ($\chi^2 = 4.014$, $p = .045$, $df = 1$), meaning the

ACT composite score alone acceptably distinguished between students who remained and dropped out, but Nagelkerke's R^2 of .017 indicated a weak relationship between the predictor variable and retention status. In fact, ACT as a predictor variable performed well in predicting who stayed, but was less able to accurately predict who left. The test against a full model, including ACT composite score and three subjective task values, was statistically significant (χ^2 = 26.138, $p < .01$, $df = 3$). Nagelkerke's $R^2$of .12 indicated a stronger relationship than the ACT-only model. Overall prediction success of the full model, which included changes in motivational variables and ACT composite score, was 80.9% (98.7% for predicting who was retained and 13.9% accuracy for predicting who was not retained). The Wald criterion demonstrated that changes in interest made a significant contribution to prediction of retention status (β= .662, SE = .170, Exp(β)= 1.94, p< .001); an increase in interest in engineering was statistically significantly associated with remaining enrolled in engineering the following year. Changes in attainment value and perceived cost value were not statistically significantly related to enrollment status.

Table 3
Logistic Regression Analyzing the Association between Changes in Task Valuesand Retention Status (N=376)

Variable	*β*	*SE*	*EX (β)*
Model 1			
ACT composite score	.082*	.041	1.085
Predictive Percentage			79%
Model 2			
ACT composite score	.083*	.042	1.087
Interest level change	.662*	.170	1.939
Change in attainment value	.355	.206	1.426
Change in perceived psychological cost value	-.129	.189	.879
Predictive Percentage			80.9%

Note. * p< .05

Discussion

Overall, our findings suggest that after accounting for general academic ability (as measured by students' ACT composite scores), changes in students' interest, attainment value, and perceived psychological cost value for engineering explain a modest amount of variance in first semester overall GPA. As hypothesized, some changes in task values were associated with achievement. Specifically, increases in interest and attainment value (perceived meaningfulness) for engineering were positively associated with achievement, and increases in perceived psychological cost value (perceiving affective and emotional stressors and drawbacks of engineering) were negatively associated with academic achievement. It is important to highlight that these relations are likely bidirectional in nature. For example, it is possible that students who perceive engineering to be associated with emotional and stress-related costs will reduce engagement, lowering achievement. But it is equally plausible that students who struggle

academically in engineering would perceive greater costs associated with engaging in engineering. Future research should more closely investigate these nuanced relationships.

Change in interest stood out as a critical predictor of one-year retention status. Task values are related to choices or decision-making processes, which includes persistence[1]. Although persistence is critical to retention in engineering fields, it is not surprising that an increase in interest level is associated with first year retention. In particular, an increase in interest greatly helped to predict which students remained in engineering. Engineering educators have long known that freshmen engineering students should be exposed to real-world relevance in their first year course work. This research confirms its importance by highlighting that increases in interest in engineering are associated with both achievement and retention; a new way educators at this university have been emphasizing real-world relevance is through a study of the Engineering Grand Challenges[19]. Students are challenged to think critically as they propose designs to address some aspect of one of the challenges and then explore ethical implications of their proposed designs. Although the logistic regression model was less successful in predicting who changed majors out of engineering (the model only accurately predicted fewer than 15% of those cases), this is somewhat consistent with prior research that showed predicting who achieves academically is more straightforward than predicting who underachieves[20]. In other words, there is often more variability underlying reasons for underachievement, and the same is likely true for students who change majors out of engineering to choose different educational pathways.

Limitations& Future Directions

Some limitations need to be considered while generalizing the results of this study. The overall regression model (predicting achievement from changes in task values) explained a modest amount of variance, but this is to be expected given that subjective task values are more strongly predictive of engagement and choices to persist as opposed to achievement. In addition, the measure of interest for engineering contained only one item; therefore, internal consistency could not be calculated. Relatedly, it is possible that somewhat low internal consistency for perceived psychological cost value affected our ability to detect relations between changes in this construct and achievement and retention. Future research should examine interest with a multi-item measure and continue to explore the measurement of perceived psychological cost value. Overall, the prediction success for students who did not remain enrolled in engineering school is relatively low, as the model was better at predicting who remained enrolled based on increasing interest value. Finally, the diversity of the current sample as it pertains to race and ethnicity is a limitation. Future research with changes in motivational beliefs should aim to replicate these findings with samples that are more diverse with regard to race and ethnicity.

Conclusions

Overall, these findings demonstrate that changes in motivational beliefs about engineering (interest, value, and perceived psychological costs) are associated with first semester academic achievement. To improve academic performance and retention rate, potential interventions could entail helping students develop an identity as an engineer, and identifying strategies to alleviate excessive worries about what happens when failure occurs. For example, this could involve

helping students reframe a poor exam grade as something within their control (effort) rather than indicative of low ability and a sign that they should drop out of engineering. The finding that increases in personal interest are associated with remaining enrolled in engineering renews the emphasis on the need to implement programs in the first year that expose students to real-world engineering applications and relevance since such programs are designed to promote interest in engineering.

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