An Examination of Students' Motivation in Engineering Service Courses

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***Abstract*—To increase the number of science, technology, engineering, and mathematics (STEM) graduates, educators need to identify ways to increase student persistence from entry until graduation. The objectives of this study are to determine (1) if motivation affects learning outcomes in engineering service courses and (2) whether students' level of motivation tracks with specific engineering disciplines. Students enrolled in a sophomore-level engineering service course were surveyed to examine their motivation in engineering service courses and to assess the relationship between their motivation and their achievement and desire to persist in the engineering discipline. The survey measures for self-efficacy, task value, and achievement goals in engineering were created and evaluated during an initial pilot study. Initial results showed internal consistency among the items in each measure.**

***Keywords*—student motivation; self-efficacy; task value; achievement goal; academic achievement; intentions to persist; engineering service course**

I. Introduction

Attrition of undergraduate students in engineering programs is at its highest level during the first two years [1, 2]. In most engineering programs, undergraduate students are required to take entry-level engineering courses that are not discipline specific and are therefore considered service courses. Service courses are often characterized as having large class sizes (> 50 students) [3]. Students in these courses have indicated that compared with other courses in their discipline, service courses have a more demanding course load and they have smaller amounts of interaction with instructors in these courses [1]. Engineering students develop personal beliefs and attitudes about engineering during these service courses that influence their decision to persist within their current engineering discipline. Student motivation in these courses is worth examining to better understand its relationship to academic achievement and intentions to persist in engineering. Examining whether these relationships differ as a function of gender, class-standing, and engineering sub-discipline (major) is also warranted.

Though engineering students' motivation has been examined in previous research, most researchers use omnibus measures or measures for engineering-related domains such as mathematics and science [e.g., 4]. Our study seeks to determine the relationship of motivation constructs (i.e., self-efficacy, task value, achievement goals) to achievement and persistence using measures providing clear activities and tasks in engineering and not only in engineering-related domains. Ultimately, we want to know which motivation construct better predicts student achievement and intent to persist in engineering.

II. Theoretical Framework

With interest in multiple motivation constructs, we begin by examining students' engineering self-efficacy. Using social cognitive theory as our framework, we propose that students' continued matriculation in engineering programs may be due (in part) to their self-efficacy - the belief they hold about their capabilities. Social cognitive theory is based on the view that personal factors, behavioral factors, and environmental factors are interconnected and affect one another [5]. Bandura's [5] research showed that the belief individuals hold in their capability to bring about results is a primary motivator in a variety of life situations. Self-efficacy helps determine the amount of effort people exert in an activity, and their persistence and resilience in the face of adversity [6]. Students who believe they are capable of performing certain engineering tasks are typically more motivated to complete them [5].

III. Method and Participants

Participants for this ongoing study include students enrolled in an introductory materials science and engineering (MSE) service course at a large southeastern research-intensive university. Table 1 shows the respondents' demographics.

TABLE I. Characteristics of Respondents

Factor	**Fall 2012** (N = 64)	**Spring 2013** (N = 97)
Gender		
Male	64.1 %	71.1 %
Female	35.9 %	28.9 %
Class-Standing		
Sophomore	59.4 %	52.6 %
Junior	29.7 %	41.2 %
Senior	7.8 %	6.2 %

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Pursuing 2nd Degree	3.1 %	0 %
Academic Major		
Bioengineering	32.8 %	12.4 %
Industrial Engineering	1.6 %	27.8 %
Materials Science & Engineering	18.8 %	12.4 %
Mechanical Engineering	43.8 %	45.4 %
Other	3.0 %	2.1 %

The pilot survey was administered in the fall semester of 2012. A revised survey was administered to another cohort of students at the beginning of the spring 2013 semester. After evaluation of the initial self-efficacy scales, most items were retained. One item originally considered a source of self-efficacy (i.e., I can use engineering tools to assist me in completing engineering assignments) was added to the general engineering self-efficacy scale. The data collection instruments used for this study were approved by the institution's Institutional Review Board.

Students were asked to complete an online survey about their attitudes and beliefs about engineering. Survey items were either created or adapted from validated measures. Engineering self-efficacy measures (i.e., general engineering self-efficacy, engineering skills self-efficacy, and materials science engineering [MSE] self-efficacy) were designed in consultation with experts in engineering education and self-efficacy and in keeping with Bandura's [7] guidelines for constructing self-efficacy scales. Using a 6-point Likert-like scale (1 = *completely uncertain*, 6 = *completely certain*), students indicated the level of certainty that they can do specific engineering tasks. Table 2 shows examples of items in each scale. The scales were found to be reliable with Cronbach's alpha values greater than 0.70 [8] (Table 3).

TABLE II. EXAMPLE OF ITEMS IN EACH SELF-EFFICACY SCALE

Scale	Example
General Engineering Self-Efficacy	I can do a good job on almost all my engineering coursework if I do not give up.
Engineering Skills Self-Efficacy	I can design new things.
Materials Science & Engineering Self Efficacy	I can explain the difference between primary and secondary bonding in materials.

TABLE III. RELIABILITIES OF ENGINEERING SELF-EFFICACY SCALES

Scale	Alpha	
	Fall 2012	*Spring 2013*
General Engineering Self-Efficacy	0.93	0.91
Engineering Skills Self-Efficacy	0.92	0.94
Materials Science & Engineering Self Efficacy	0.94	0.96

To examine the relationship between self-efficacy and academic achievement, students' grades in the service course were obtained. Two dimensions of intentions to persist in engineering were measured, namely, academic persistence (intent to graduate with an undergraduate engineering degree) and professional persistence (intent to practice engineering for at least three years after graduation) [9].

IV. PRELIMINARY RESULTS AND DISCUSSION

Zero-order correlations were calculated among the variables of interest. General engineering self-efficacy was positively related to grades in fall 2012 ($r = 0.42$, $p < 0.01$) and to MSE self-efficacy ($r = 0.35$, $p < 0.01$). Previous studies have shown a positive relationship between self-efficacy and academic achievement [10, 11]. Successful academic performance in an introductory class in MSE calls for the execution of MSE-related skills (e.g., identifying effects of defects on mechanical properties of solids) and general engineering tasks (e.g., learning engineering concepts) [12]. Spring 2013 grades are not available at this time and will be included in the correlational analysis when obtained. In the spring semester of 2013, general engineering self-efficacy and engineering skills self-efficacy were significantly related to professional persistence ($r = 0.31$, $p < 0.01$; $r = 0.42$, $p < 0.01$, respectively). Judgments of capabilities matched to specific outcomes afford the greatest prediction of behavioral outcomes such as practicing engineering [13]. Being able to perform general and specific engineering skills necessary for engineering practice likely solidifies students' intentions to be engineers. On the other hand, none of the three engineering self-efficacy measures was significantly related to academic persistence. This result suggests that other factors may motivate students to enroll in engineering courses and to complete their engineering degrees.

Independent-samples *t* tests revealed significant gender differences in participants' engineering skills self-efficacy and MSE self-efficacy. Men ($M = 4.89$, $SD = 0.67$) reported significantly higher engineering skills self-efficacy scores than women ($M = 4.54$, $SD = 0.66$), $t(95) = 2.38$, $p < .05$. Men ($M = 3.25$, $SD = 0.99$) also reported significantly higher MSE self-efficacy scores than women ($M = 2.53$, $SD = 0.83$), $t(95) = 3.34$, $p < .01$. Our findings are consistent with other studies that found significant gender differences in students' self-efficacy in engineering [14, 15]. Previous work has shown that women seem to report a lack of self-efficacy related to specific areas of skill, knowledge, or ability [16].

Due to the small number of senior students in the sample ($n = 6$), class-standing groups were collapsed into two categories: lowerclassmen (i.e., freshmen and sophomores) and upperclassmen (i.e., juniors and seniors). The independent-samples *t* test revealed a significant mean difference between upperclassmen and lowerclassmen. Upperclassmen reported higher general self-efficacy scores ($M = 5.07$, $SD = 0.69$) than lowerclassmen ($M = 4.80$, $SD = 0.64$), $t(95) = 2.08$, $p < .05$. This result echoes previous findings that lowerclassmen have significantly lower self-efficacy [17]. Students further along in their engineering programs might be expected to have higher engineering self-efficacy due to their successful completion of requirements in their engineering programs compared to those students who are just beginning to take courses in their major.

To understand the effect of student major on self-efficacy, an analysis of variance was performed. Results of the analysis of variance revealed a significant difference in engineering skills self-efficacy as a function of students' engineering major, $F(4, 92) = 2.69$, $p < .05$ (see Table 4 for mean values). Considering that each engineering sub-discipline requires the mastery of specialized skill sets, students may possess specific skills and beliefs about those skills depending on their major. Some engineering skills may be more relevant to one major, and therefore students in that major have more opportunities to demonstrate those skills. This possibility could explain differences in self-efficacy levels.

TABLE IV. ENGINEERING SKILLS SELF-EFFICACY MEAN SCORES BY ENGINEERING MAJOR

Engineering Major	N	Mean	Standard Deviation
Bioengineering	12	4.69	0.57
Industrial Engineering	27	4.78	0.78
Materials Science & Engineering	12	5.15	0.46
Mechanical Engineering	44	5.00	0.68

V. CONCLUSIONS AND FUTURE WORK

Through this initial and ongoing work, we have created an instrument to assess undergraduate students' engineering self-efficacy. Initial data suggest that there is a positive correlation between efficacy beliefs in general engineering and specific to MSE. Significant differences in the mean values reported as a function of gender, class-standing, and engineering sub-discipline were also found. Engineering self-efficacy was positively associated with achievement (term grades).

Our preliminary findings suggest a positive relationship between engineering self-efficacy and academic achievement. Further examination of motivation in relation to academic persistence is also necessary. Examining multiple motivation variables may be helpful for understanding the educational goals that engineering students pursue [18]. In addition to self-efficacy, we will examine the *value* students place on the tasks to be mastered and the achievement goals they have. Researchers have shown that task values are related to course plans and enrollment decisions [19] and that achievement goals are related to enrollment in major courses and to academic performance [18]. However, few have examined these constructs in the domain of engineering. Our hope is to include diverse motivation constructs to help us better understand engineering students' academic performance and intentions to persist in engineering.

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