The Importance of Belonging and Self-Efficacy in Engineering Identity

WORD COUNT (1,872)

Abstract

Retention of students in Science, Technology, Engineering, and Mathematics (STEM) disciplines is a significant concern in higher education. Identity has been identified as an important correlate of academic success that may be important in a robust model of STEM retention. The engineering identity of "early career" university engineering students and its relation to GPA, self-efficacy, and a sense of belonging was examined. Self-efficacy and belonging were demonstrated to be domain dependent. A sense of belonging was much more strongly related to identity than either GPA or self-efficacy. A strong sense of belonging, specifically in the domain of the department of their major, was critical to a strong engineering identity.

Introduction

Workforce demand for Science, Technology, Engineering, and Math (STEM) graduates has grown significantly over the past decade, with the number of jobs requiring at least a STEM bachelor's degree growing to comprise around 20% of the workforce (NSB, 2015). This growth in the STEM job sector has put significant pressure on universities to increase the number of students who graduate with STEM degrees. In their 2012 report, the President's Council of Advisors on Science and Technology emphasized the need to improve retention of STEM students to avoid a projected 1 million STEM job candidate shortfall over the next decade (Olson & Riordan, 2012). Despite the recognized importance of improving STEM graduation rates, only 40% of STEM majors successfully complete their degrees (Olson & Riordan, 2012). Research has shown that students who develop a strong sense of identity in their chosen discipline are more likely to persist to completion of STEM degrees (Hazari, Sadler, & Sonnert, 2013; Aschbacher, Li, & Roth, 2010; Aschbacher, Ing, & Tsai, 2014; Carlone & Johnson, 2007; Chemers, Zurbriggen, Syed, Goza, & Bearman, 2011).

One of the most widely accepted models of college student STEM identity was developed by Carlone & Johnson (2007). This model defines the construct of identity as being comprised of three components: recognition, performance, and competence. Of these components, competence is easily measured for large cohorts of students through traditional ability measures such as GPA and standardized test scores. The other two components, recognition and performance, are more difficult to measure requiring direct interviews and observations. Furthermore, important events contributing to both constructs, such as being given one's own project by a research advisor or speaking proficiently about science or engineering in public are only likely to occur later in a student's academic career. Neither recognition nor performance are broadly studied factors influencing student success (Richardson & Bond, 2012); however, both seem related to more thoroughly studied constructs. Performance may be strongly related to the student's belief that he or she can perform, self-efficacy. Recognition should be related to the degree one feels that he or she fits into the scientific community, the student's sense of belonging.

As Bandura stated, "…self-efficacy is defined as people's beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives. Self-efficacy beliefs determine how people feel, think, motivate themselves and behave" (Bandura, 1994). Self-efficacy (SEF) has been robustly analyzed as a significant independent predictor of academic success (Bandura 1977,1997; Zimmerman, 2000; Richardson & Bond, 2012). Beyond its use in explaining academic success, increased SEF has also been shown to increase academic persistence (Rittmayer & Beier, 2009).

A student's sense of belonging (BLG) within their academic community has also been shown to be an indicator of academic success (Pittman & Richmond, 2007). When studying college students in calculus class, Good & Dweck (2012) found that an increase in BLG within the math class lead to an increase in intention to pursue math in the future.

This study will address the following research questions: [RQ1] How do the constructs of BLG, SEF, and competence measured by GPA relate to engineering identity? [RQ2] Are the constructs SEF and BLF domain dependent? [RQ3] Are there domains where SEF or BLG are more strongly related to engineering identity?

Methods

This research was conducted at an eastern land-grant university serving approximately 30,000 students between the fall 2015 and spring 2017 semesters. This study includes the engineering students (77% male) that were enrolled in the introductory calculus-based physics courses: Physics 1 and Physics 2. Most students in the courses were freshmen and sophomores. These courses were team taught and employed active learning techniques.

A modified version of the "Self-Efficacy for Learning and Performance" subscale from the Motivated Strategies for Learning Questionnaire (MSLQ, Pintrich, Smith, Garcia, & McKeachie, 1993) was used to measure the students' SEF. SEF was measured in five domains: physics class, mathematics class, other science classes, classes in the department of major, and a student's intended profession. Questions were created by replacing words such as "class/course" in the MSLQ with words that were specific to each domain. For example, a question from the MSLQ "I'm certain I can master the skills being taught in this class" was modified to "I'm certain I can master the skills being taught in this physics class." Each subscale contained 6 questions. All subscales produced a Cronbach's alpha of .89 or above. Confirmatory Factor Analysis (CFA) showed an excellent fit with a Comparative Fit Index (CFI) of .94.

BLG was measured with a belonging instrument adapted from Good & Dweck (2012). This instrument measured belonging in the "the math community." Similarly to SEF, the instrument was modified to measure BLG in four domains: physics class, mathematics class, other science classes, and a student's department of major. These subscales contained 5 questions and had a Cronbach's alpha of .91 or above. CFA demonstrated excellent fit with a CFI of .97.

Students' engineering identity (ENGID) was measured by using a combination of identity items from the PRISE survey discussed by Hazari et al. (2013), questions developed by Chemers et al. (2011), and the ISME survey by Aschbacher et al. (2014). This produced an 8-question scale with a Cronbach's alpha of .89. The questions were rephrased to specifically investigate a student's ENGID. Interviews were conducted to verify the validity of the modified subscales.

A total of 3,084 students completed Physics 1 or 2 for a grade during the time studied. Only engineering students who completed the survey were included in the study leaving a total sample size of 969 with 798 unique students. Some students matriculated through both courses. Cumulative college grade point average (GPA) will be used as a measure of competence. The students' ACT math percentile was also explored as the measure of competence and performed similarly to GPA.

Results

Table 1 presents the overall averages as well as well as averages disaggregated by course. To analyze the differences between the two courses, *t*-tests with a Bonferroni correction were used; there were no significant differences between the two courses. As such, the data were analyzed by aggregating the two courses. Responses from students in both courses were averaged to produce a single response for each participant.

[RQ1] *How do the constructs of BLG, SEF, and competence measured by GPA relate to engineering identity?* A student's overall SEF and BLG were constructed by averaging over the domain specific subscales. The correlation matrix, presented in Table 2, shows that BLG and SEF were significantly correlated with a large effect size. BLG was also significantly correlated, with a large effect size, with ENGID; however, SEF was significantly correlated with ENGID, but with a medium effect size.

Hierarchical linear regression (HLR) was employed to further explore the relation of these variables; the results are presented in Table 3. In Model 1, GPA was not a significant predictor of ENGID. Taken independently in Models 2 and 3, SEF and BLG explained substantial variance in ENGID, R^2_{adj}=.10 and .28 respectively. The combination of GPA and BLG in Model 4 was a significant improvement over Model 2, but explained only 1% additional variance. Model 5 which added SEF to Model 4 was not a significant improvement over Model 4.

[RQ2] *Are the constructs SEF and BLG domain dependent?* Bandura (1977) cautioned that SEF was domain dependent. SEF toward STEM courses has been shown to be domain dependent (Authors, 2017). Similarly, one expects BLG to depend on the context. The sub-scale averages of SEF and BLG are presented in Table 4. Comparing Physics 1 and Physics 2, *t*-tests showed that only SEF in the physics class domain was significantly different [$t(890.61) = 3.15$, $p = .002$, $d = .21$]. As such, the remaining analysis will aggregate the two classes.

In the aggregated dataset, a repeated-measures ANOVA demonstrated differences between the domains of SEF [$F(4, 4635) = 18.66$, $p < .001$]. Post-hoc analysis using pairwise *t*-tests with a Bonferroni correction showed most domains were significantly different. The difference was largest between SEF in physics class and the profession with a medium effect size [$p < .001$, $d = .51$]. Smaller differences existed between other domains: department/major and physics class [$p = .001$, $d = .32$], department/major and the profession [$p = .001$, $d = .20$], math classes and physics class [$p = .006$, $d = 0.34$], physics class and other science class [$p < .001$, $d = -.25$], and other science classes and the profession [$p < .001$, $d = .27$]. Other pairs were not significant.

ANOVA also showed significant differences between BLG domains [$F(3, 3708) = 9.35$, $p < .001$]. Post hoc analysis showed department/major and physics class [$p < .001$, $d = .30$] as well as math class and other science classes [$p < .001$, $d = .24$] were significantly different with medium effect sizes. Other differences were not significant.

[RQ3] *Are there domains where SEF or BLG are more strongly related to engineering identity?* Table 5 presents the results of a linear regression with ENGID as the dependent variable and domain specific SEF and BLG as the independent variables. The use of the BLG domains explained more variance in ENGID than when using the overall average BLG in Table 3—Model 2; R^2_{adj} increased from .28 to .33. The SEF sub-scales in Table 5 also explained more variance than the average SEF in Table 3—Model 3; R^2_{adj} increased from .10 to .12. BLG in department/major [$\beta = .47$, $p < .001$] and SEF in the profession [$\beta = .31$, $p < .001$] were the largest regression coefficients.

Because BLG in the department/major and SEF in the profession had the largest regression coefficients in Table 5, HLR analysis was used to explore the relation between these sub-scales and ENGID (Table 6). Model 4 showed that including GPA and BLG in the department/major was a significant improvement over Model 2 and explained 1% additional variance. This model explained 4% more variance than Model 4 in

Table 3 using the overall BLG. Table 6-Model 5, which added SEF toward the profession, was a significant improvement over Model 4 and explained 1% additional variance in ENGID.

Discussion/Conclusion

This study showed that GPA on its own has little relation to a student's ENGID. While self-efficacy was related to ENGID, it was a sense of belonging that was most related to ENGID. This suggests Carlone & Johnson's model (2007) of STEM identity may not extend to "early career" university students. Competence, measured by GPA, was not predictive of ENGID. SEF and BLG which may serve as early precursors of performance and recognition in Carlone & Johnson's model were not equally important. This study also provided additional evidence that both BLG and SEF are domain dependent. This indicates that a general measurement of either quantity may not accurately translate into a specific domain. BLG in the department/major and SEF toward the profession were more strongly related to ENGID than the other sub-scales. As such, efforts by departments of engineering to welcome their students into a professional community producing a sense of belonging may be particularly important in the improvement of STEM student retention. The regression coefficient of GPA was negative in many models; additional study is needed to understand the reason for this relation.

Acknowledgements

The work was supported by National Science Foundation award #1561517.

Tables and Figures

Table 1 – Descriptive Statistics

	Overall (N = 929)	Physics 1 (N = 531)	Physics 2 (N = 398)
GPA	3.26 ± .59	3.25 ± .66	3.27 ± .50
ENGID	4.02 ± .72	4.01 ± .70	4.02 ± .74
BLG	4.17 ± .57	4.10 ± .58	4.18 ± .57
SEF	4.13 ± .58	4.16 ± .57	4.19 ± .58

Note: GPA was measured on a 4-point scale. ENGID, BLG, and SEF were measured on a 5-point Likert scale.

Table 2 – Correlation Matrix

	ENGID	BLG	SEF	GPA
ENGID	-			
BLG	$.53^c$	-		
SEF	$.32^c$	$.57^c$	-	
GPA	-.04	$.14^c$	$.23^c$	-

Note: Superscript "a" denotes p < .05, "b" denotes p < .01, and "c" denotes p < .001.

Table 3 – Hierarchical Linear Regression – Dependent Variable ENGID

	Variable	B	SE	β	*t*	*p*	R^2_{adj}	ΔF	*p* (ΔF)
Model 1	GPA	-.05	.04	-.04	-1.10	.270	.00	1.22	.270
Model 2	BLG	.67	.04	.53	17.69	<.001	.28	313.00	<.001
Model 3	SEF	.40	.04	.32	9.51	<.001	.10	90.50	<.001
Model 4	BLG GPA	.69 -.14	.04 .04	.55 -.11	18.20 -3.81	<.001 <.001	.29	14.51	<.001
Model 5	BLG GPA SEF	.65 -.15 .07	.05 .04 .05	.52 -.12 .06	14.31 -4.03 1.51	<.001 <.001 .132	.29	2.27	.132

Table 4 – Descriptive Statistics by Domain

Domain	Overall (N = 929)	Physics 1 (N = 531)	Physics 2 (N = 398)
Belonging			
Physics Class	4.01 ± .73	3.98 ± .75	4.05 ± .72
Math Classes	4.18 ± .64	4.17 ± .65	4.18 ± .64
Other Science Classes	4.10 ± .65	4.09 ± .65	4.11 ± .65
Department/Major	4.21 ± .61	4.20 ± .59	4.23 ± .62
Self-Efficacy			
Physics Class	3.94 ± .77	3.87 ± .79	4.03 ± .73
Math Classes	4.18 ± .64	4.15 ± .65	4.21 ± .64
Other Science Classes	4.11 ± .64	4.09 ± .63	4.14 ± .65
Department/Major	4.16 ± .62	4.12 ± .63	4.21 ± .59
Profession	4.28 ± .58	4.27 ± .58	4.29 ± .57

Note: All averages are measured on a 5-point Likert scale.

Table 5 – Multiple Regression – Dependent Variable ENGID

Variable	B	SE	β	*t*	*p*	R^2_{adj}
Belonging						
BLG: Physics Class	-.10	.05	-.10	-2.04	.042	.33
BLG: Math Classes	.07	.06	.06	1.24	.216	
BLG: Science Classes	.17	.07	.15	2.30	.022	
BLG: Department/Major	.55	.06	.47	8.63	<.001	
Self-Efficacy						
SEF: Physics Class	.03	.05	.03	.66	.508	.12
SEF: Math Classes	.14	.07	.12	1.97	.049	
SEF: Science Class	-.17	.09	-.15	-1.91	.057	
SEF: Department/Major	.06	.09	.05	.67	.501	
SEF: Profession	.39	.07	.31	5.18	<.001	

Table 6 – Hierarchical Linear Regression – Dependent Variable STEM Identity

Model	Variable	B	SE	β	*t*	*p*	R^2_{adj}	Δ*F*	*p* (Δ*F*)
Model 1	GPA	-.05	.04	-.04	-1.10	.270	.00	1.22	.270
Model 2	BLG: Department/Major	.67	.03	.57	19.39	<.001	.32	375.9	<.001
Model 3	SEF: Profession	.44	.04	.35	10.54	<.001	.12	111.10	<.001
Model 4	BLG: Department/Major	.69	.03	.58	19.94	<.001	.33	16.34	<.001
	GPA	-.14	.04	-.12	-4.04	<.001			
Model 5	BLG: Department/Major	.64	.04	.54	15.83	<.001	.34	5.87	.016
	GPA	-.15	.04	-.13	-4.26	<.001			
	SEF: Profession	.10	.04	.08	2.42	.016			

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