

Step-Outs to Stars: Engineering Retention Framework

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The Step-outs to Stars Engineering Retention Framework

Abstract

This research paper, grounded in Expectancy-Value Theory, investigates the relationship between interest, first semester GPA and first year retention in engineering. The research resulted in a purposefully parsimonious framework that can be readily implemented to provide useful discrimination for predicting retention, and can be used when investigating other factors related the retention. Quadrants based on interest were created based on results from logistic regression analysis which showed a difference in the probability of retention between students with equal, less, or no interest in engineering compared to other fields, and those with only or more interest in engineering. GPA quadrants were created based on average GPA. The usefulness of the framework is demonstrated by investigating gender as a variable. The analysis showed a difference of retention rate between males and females only in the quadrant with high grades and low interest.

Introduction

Pressures to increase the retention rate of post-secondary students has risen due to state and federal governmental concerns over retention and student debt, and the use of retention and graduation rates to rank institutions of higher learning¹. As a result, student retention is one of the most studied subjects in higher education². A subset of this literature concentrated on retention of engineering students has also grown, partly due to the national discussion about the potential shortage of engineers in the workforce (see Charlette³ and United States Congress Joint Economic Committee⁴ for a discussion of both sides of the debate). Multiple reasons exist for studying engineers as a separate group including: a) the differences in the demands of the engineering curriculum compared to other college majors⁵; b) the types of students who choose to study engineering^{6,7,8}; and c) a belief that factors affect engineering students' performance and persistence decisions differently than non-engineering students⁹.

Studies in engineering retention have been influenced by factors from the college retention literature. These factors include pre-entry characteristics such as skills and abilities^{10,11} family background¹², institutional experiences^{13,14}, and finances¹⁵. While research in college retention has focused on integration into the university, research in engineering retention has focused more on integration into the engineering culture¹⁶.

Factors not related to college retention, but instead related to college major and career choice, have also been investigated in studies of engineering retention. Some studies have focused on why students made the decision to study engineering^{17,18,19}, while others have focused on students' decisions to leave engineering^{20,21}. Collectively, these studies investigated factors such as the importance of available jobs, good pay, interest in the field, and perceived ability to perform.

Other factors related to social and psychological factors have also been investigated with respect to retention in engineering or other majors. These factors include things such as beliefs on effort and intelligence^{22,23}, feeling of belonging²⁴ and grit²⁵.

Thus the literature is ripe with factors that have been related to retention of engineering students, as well as, general college students. As such, retention of college students in general, and engineering students in particular, is a complex issue with many interrelated factors that affect students differently and are not easily measurable for all students. This study very intentionally sought a parsimonious, simple model that could be very readily implemented. Our purpose was to explore if such a simple model might provide useful discrimination for predicting retention, and thereby potentially serve as an actionable framework for designing and implementing retention strategies. We also were interested in exploring if investigating other factors within the framework might help explain some conflicting results within the engineering retention literature.

Theoretical Framework

Many of the studies on engineering retention are framed through the lens of college retention. Although there is value in that perspective, this study was framed in expectancy value theory²⁶, a theory used in the college major and career choice literature^{27,28}. Expectancy value theory, a motivational theory, attempts to explain individuals' choice of behavior based on their expectation of success and the value they place on the task or outcome of the task. The behavior can be related to the decision to work on a task, whether or not to persist at a task, or the amount of effort to invest in a task²⁸. Atkinson, who was the first to form a mathematical model including expectancies, values and behaviors, hypothesized that a person's expectancy was based on a motive to find success and a motive to avoid failure²⁹.

Expectancy

Bandura³⁰ discussed two types of expectancy: outcome expectancy and efficacy expectancy. Outcome expectancy deals with the belief that a behavior will lead to a desired outcome; for example, one belief might be that "If I study hard, I will get an A in this class." Efficacy expectancy concerns an individual's belief that he or she can be successful in completing a given task, such as the belief that he or she can complete an engineering degree. The current study focused on efficacy expectancy.

An individual's level of expectancy is impacted by his/her competency, self-efficacy, and their perceived level of control over the task³¹. Weiner³² states that expectancy will be lower if the individual's perceived ability is low or his/her perceived difficulty of the task is high. He also states that if an individual assumes that conditions will remain the same and that his past success was due to ability, he will anticipate success in another similar task. Since many students measure success by GPA, first semester GPA was used as a measure of expectancy in the current study. Further support for using GPA to measure expectancy is given in the literature review section.

Value

Value is related to the incentive or gain from doing or completing a task³¹. Eccles and Wigfield³¹ list four components that determine the value of completing a task: intrinsic, utility, attainment, and cost. Intrinsic value is related to the enjoyment a person gets from engaging in the task. The more interested one is in the task, the higher the intrinsic value. Utility value is based on the contribution the activity makes toward meeting a long-term goal, such as getting a degree. Attainment value includes the benefits gained from completing the task, such as finding a high paying job. Attainment value can also be related to less concrete results such as confirming an aspect of one's self-schema¹⁶, or the relevance of engaging in the task. Finally, cost value includes the effort needed to engage in the task, as well as the inability to do other tasks, and emotional costs such as anxiety and fear. The current study used interest in engineering as a measure of intrinsic value. The study was not concerned with why the student was interested in engineering, only how their interest in engineering compared to interest in other fields. Further support for using interest as a measure of value is given in the literature review section.

Related Literature

Why Students Choose to Study Engineering

A number of survey based studies have been conducted to determine why students choose to study engineering. Some have investigated solely engineering students¹⁷, while others also included science, technology and math majors^{19,33}. Conclusions from these studies were dependent upon the design of the survey (wording of the questions and answer options) and the population sampled. For example, surveys that allow multiple responses, rated responses or open responses may come to different conclusions on which factors influenced students to study or leave engineering³⁴.

Harris International conducted a national online survey of college students currently pursuing engineering, as well as science, technology, and math fields¹⁹. Results of the survey showed 86% of the students were motivated to choose their major based on the belief they could get a good salary; 68% were motivated by intellectual stimulation and challenges; and 66% were motivated by job potential.

The same three factors – job availability, good pay, and interest – were cited in published studies at University of Louisville¹⁷ and Arizona State University³³. In the Arizona State University study, students were asked why they were interested in engineering or applied science, and were given seven responses to rank in order of importance. Of their top three responses, 79% selected *Potential good salary*, 72% selected *Interesting work*, and 63% selected *Many job opportunities*. In a University of Louisville study¹⁷, students in the 2011 freshman cohort were asked to respond to nine factors and rank the top three they considered when determining what career to pursue. *Holds my interest*, was chosen by the highest percentage of students as their top factor (34%) and was selected by the highest percentage of students in their top three factors (64%). The next highest response was *That I feel confident jobs will be available when I graduate*, which was selected as the top factor by 21% of the students and in

the top three by 56%. The final response that was selected in the top three by over half of the students was *That pays well*.

In the University of Louisville¹⁷ study students were also asked “Why did you chose to study engineering?” The responses included good jobs and good pay, but also included *Good at math and science* and sources of influence such as parents or teachers encouragement. Over 90% of the students selected *Good in math and science* as one of potentially multiple responses. Clearly, the overwhelming majority of engineering students think they are good in the topics that are the foundation of an engineering education. Thus one can conclude they expected to be successful when they choose to study engineering.

Why Students Left Engineering

Other studies have gathered data from students who started in engineering, but subsequently left. A well-referenced multi-institutional ethnographic study²¹ investigated why students who were expected to be successful based on their SAT math scores switched from engineering while others did not. Lack or loss of interest in engineering was one of the top contributing factors to students’ decisions to switch out of engineering. A male student who switched out of engineering pointed out the importance of having interest in engineering: “You have to have the interest and the desire. I don’t think the problem is preparation. I think its more interest.” (p. 179). Other top factors cited in the study related to difficulty of the curriculum, poor teaching and advising, and loss of confidence due to poor grades.

Loss of interest in engineering was also documented as a major cause for leaving engineering in a study that analyzed survey results from students who transferred out of engineering at the University of Pittsburgh³⁵. Of the 115 freshmen who completed the survey, 72% selected *Lost interest/developed new interest* as a factor in their decision to leave engineering. Additionally, 66% selected *Came to dislike engineering/studying engineering*, and 25% cited *Academic problems*.

Seymour and Hewitt²¹ reported that 25% of the students who switched from engineering cited poor grades as a factor in their decision to switch and 40% cited it as a concern. Shuman, et al.³⁵ showed that students on academic probation accounted for half the students who left engineering. Other research has shown a statistically significant difference in the GPA for students who remained in engineering versus those who left the university or switched to another major^{36,37,38,39}. Hartman and Hartman¹³ found significant difference in average GPA for males who left engineering and those who stayed, but there was no significant difference for females.

For some students, grades help define their self-worth and a drop in grades can be devastating and can lead students to switch out of challenging disciplines such as engineering²¹. GPA is also important to students due to university-established GPA requirements for scholarships and academic probation.

Based on an unpublished study at the University of Louisville⁴⁰, students start engineering school with expectations of earning high GPAs. In that study, during the first week of class students in the 2012 freshman cohort were asked on a survey what they thought the chances were they would receive a GPA of 3.5 or above and 56% answered *Very good* or *Good*.

When asked the chances they would receive a 3.0 or above, 86% of the students responded *Very good* or *Good*. This expectation is most likely based on the GPAs they earned in high school (38% of this cohort had a high school GPA of 4.0 or above). At the end of first semester only 26% of the cohort had a GPA of 3.5 or above and 44% had a GPA of 3.0 or above.

Justification of Variables Used to Create the Step Out to Stars Framework

The review of literature presented here shows interest in engineering is a key reason that students choose to study engineering, while loss of interest is also a key reason students leave engineering. Since the other top indicators of value explored in the literature, job outlook or salary projections for engineers, are not mentioned in studies investigating why students leave engineering, interest is a logical measure of value to use when looking at engineering students' decisions to leave or to continue to study engineering. In fact, the justification for considering interest in engineering as a key factor in engineering retention is so strong, we argue studies of retention in engineering should systematically include an interest variable in their models. How individuals develop interest is a complex issue due to the many interrelated factors that can impact an individual's level of interest in a field, and the variety of ways factors impact individuals differently. The current study was only concerned with the level of students' interest in engineering compared with interest in other fields, not the source of their initial interest or source of their decrease in interest.

The use of GPA to measure expectancy is supported by the research discussed above which demonstrated that many students choose engineering as a field of study due to the belief they are good in math and science and the belief they will perform well in engineering, which is most likely due to receiving high grades in the past. The loss of confidence students experience when their GPA drops²¹ also supports using GPA as a measure of expectancy.

Given that both interest and GPA performance have been repeatedly established as important factors in students' decisions when both deciding to study engineering and deciding to leave engineering, this study investigated at what level of interest and GPA performance the likelihood of a student being retained in engineering changed. This knowledge was then used to create a framework that can be used to predict retention, as well as, serve as an analytic mechanism to investigate other variables' effects on retention.

Research Methods

Participants

The participants in this study were all first-time, full-time students in fall of 2012 at one large metropolitan research institution. The freshman cohort consisted of 430 students. Data from 352 students (82% of the cohort) were used in analysis to determine the threshold value for interest. The ethnic and gender distributions of the participants were similar to the entire 2012 cohort and other recent cohorts at the same university (see Table 1). The sample was less ethnically diverse and had a higher percentage of females than the national population of engineering students⁴¹.

Table 1
Ethnic and Gender Distribution of Participants Compared to the Cohort

	In the cohort	Included in analysis on interest
Females	93 (22%)	79 (22%)
Males	337 (78%)	273 (78%)
Caucasians	365 (85%)	299 (85%)
Asians	17 (4%)	12 (3%)
Hispanic/Latino	17 (4%)	15 (4%)
African American	14 (3%)	12 (3%)
Two or more races	13 (3%)	10 (3%)
Nonresident Alien	2 (< 1%)	2 (< 1%)
Other	2 (< 1%)	2 (< 1%)
First semester GPA	2.71 (<i>SD</i> = .98)	2.84 (<i>SD</i> = .87)
Composite ACT score	28.4 (<i>SD</i> = 3.14)	28.5 (<i>SD</i> = 3.14)

Data Collection

Data used to determine the students' level of interest in engineering were taken from a survey given during week 13 of the fall 2012 semester. The survey was administered by employees in the Office of Institutional Effectiveness and completed by students in Introduction to Engineering, a required course for all freshman engineering students. No rewards or class credit were given for completing the survey, however time was allotted during class. The survey took approximately 10 minutes to complete and included questions on a variety of topics. A similar survey was administered during week one of the semester (week 1 survey). Responses on this survey were used in post hoc analysis to determine if students' level of interest changed throughout the semester.

Measures

Of the three top factors students choose to study engineering (job availability, good pay, and interest) interest in engineering is the only factor that was also given for a reason to leave engineering. This study was interested in the student's interest in engineering compared to other fields, so the following question was asked and students were able to select only one answer.

Which of the following statements best describes your interest in engineering?

- 1. Very low interest--I'm not interested in engineering; I chose engineering for reasons other than interest.*
- 2. Low interest--I have an interest in engineering but stronger interest in another field(s).*
- 3. Medium interest--I am interested in engineering and equally interested in another field(s).*
- 4. High interest--I am very interested in engineering, but also think I could be happy in another field.*
- 5. Very high interest--I am so interested in engineering that I could not imagine myself studying anything else.*

Students' first semester GPA was used as a measure of expectancy. First semester GPA for engineering students at the institution studied generally includes grades on the following courses: Engineering Calculus, Chemistry, and Introduction to Engineering. Students' retention in engineering status after one year and their first semester GPAs were extracted from student records maintained by the university. A student was considered retained in engineering if in the fall of their second year they were enrolled in the university and their academic unit was engineering.

Missing Data

The National Center of Education Statistics (NCES) requires missing data analysis on their studies with response rates lower than 85%⁴². Since the response rate to the survey was 82%, we investigated the ACT scores and first semester GPA of students who did not participate in the study compared to those who did participate. The non-participants did have statistically significant lower ACT math and science scores and first semester GPA compared to the participant group. However, when combining both the participants and nonparticipants into one group and comparing this overall full cohort with the subset of participants, there was no statistically significant difference in any of the ACT subject scores or first semester GPA between the participants and the entire cohort.

Data Analysis

The interest level and student performance and retention data were analyzed using logistic regression in SPSS version 21. Logistic regression can be used to predict a dichotomous outcome based on independent variables, or as in this study, to understand the relationship between independent variables and a dichotomous variable for the purpose of building or validating a theory⁴³. The outcome variable STATUS was coded to "1" if the student was retained in engineering at the same university (their academic unit fall 2013 was engineering), and it was coded to "0" if the student left the university or switched to another academic unit within the university.

The response to the question on interest in engineering (INTEREST) could have been treated as a continuous or categorical variable. Since the objective of the analysis was to determine if there was a difference in the likelihood of retention between specific levels of interest, the variable was treated as a categorical variable. Due to the threat to statistical validity from scarcity of data for the responses of *Very low* and *Low*, the responses of *Very low*, *Low* and *Medium* were condensed into one category (INTEREST1). The responses of *High* were entered as variable INTEREST2 and the responses of *Very High* were used as the reference category. The equation resulting from logistic regression had the following form:

$$\ln\left(\frac{p}{1-p}\right) = \beta_{constant} + \beta_{FALLGPA}FallGPA + \beta_{INTEREST(1)}INTEREST(1) + \beta_{INTEREST(2)}INTEREST(2) \quad (1)$$

Results of the Wald test were used to determine the significance of GPA and INTEREST using .05 as the criteria of statistical significance. The odds ratios for each independent variable were used to measure effect size.

Threats to Validity

The results of this study must be viewed in light of the potential threats to validity. As with all studies based on survey data, we do not know how accurately participants' responses represented their true interest level in engineering. When analysis was performed by gender the sample size, although appropriate for the analysis, was rather small. Finally, all the respondents in this study were from one cohort at the same university and were less ethnically diverse than the national population of engineering students. This might lead to a problem with external validity if the results were applied to a group of students that differ greatly from the sample used in this study.

Results

Table 2 summarizes the variables used in the logistic regression analysis and includes the variable name, variable type, potential values, and the sample size for the categorical data. The average GPA for the participants was 2.71 ($SD = .98$). If INTEREST was treated as a continuous variable using all five values of interest, the correlation between the INTEREST and GPA (.181) was statistically significant, but lower than the level ($\geq .8$) at which collinearity poses a statistical threat to validity⁴³.

Table 2

Information on Variables for Research Question 1 Analyses

Variable		Type	Potential values	<i>n</i>
Retention status (outcome variable)	(STATUS)	Categorical	0 = No 1 = Yes	92 260
Fall 2012 GPA	(GPA)	Continuous	0 to 4.0	
Interest in engineering	(INTEREST1)	Categorical	1 = Very low, Low and Medium	74
	(INTEREST2)		2 = High	197
	Reference category		3 = Very high	81

Table 3 contains the coefficient estimates and the Wald statistic for each variable along with the odds ratio and upper and lower confidence intervals of the odds ratio. These results confirmed prior research that both interest in engineering and academic performance were significant variables in predicting the likelihood of a student being retained after one year ($p < .001$). The lack of significance of INTEREST2 indicated that there is no significant difference in the likelihood of a student with very high or high interest being retained after one year, given the same GPA.

Based on the odds ratios a student was 4.6 times more likely to be retained than a student with a one point lower GPA, given the same interest level. Also a person with very high interested was about 7.7 ($1 / .131$) times more likely to be retained than a student with equal or more interest in a field other than engineering, given the same GPA.

Table 3

Results from Logistic Regression Analysis

	<i>B</i>	S.E.	Wald	df	Sig.	Odds Ratio	95% C.I. for Odds Ratio
F12_GPA	1.530	.204	56.129	1	<.001	4.618	[3.095, 6.891]
INTEREST			29.073	2	<.001		
INTEREST1	-2.034	.449	20.546	1	<.001	.131	[.054, .315]
INTEREST2	-.391	.410	.910	1	.340	.676	[.303, 1.511]

Although the purpose of the analysis was exploratory and the main emphasis of the analysis was to investigate the significance of the odds ratios, the fit statistics for the model still warranted review. The chi-square test comparing the fit between the model with no predictors and the hypothesized model indicated that INTEREST and GPA help the model fit the data significantly better than no predictors, $\chi^2(3) = 122.22$, $p < .001$. Cox and Snell R^2 was .293 and

Nagelkerke R^2 was .429, which give a sense of the magnitude of percent variance explained by these predictors. Overall the model correctly predicted the status of 83% of the students, which was better than the null model that correctly predicted status for 74% of the students. The model correctly predicted 94% of the students who were retained, but only 52% of the students who did not continue to study engineering. The lower percentage predicted for non-retained students is most likely driven by the substantially smaller sample size for that group.

Outlier analysis was performed and the model was rerun without suspected outliers. The results continued to show a significant difference in the probability of being retained between students with very high interest and very low, low or medium interest, and no difference between students with very high interest and high interest.

Step-outs to Stars Engineering Retention Framework

Based on the results of the logistic regression analysis, an engineering retention framework was constructed. The framework consists of a 2 by 2 array producing four quadrants based on first semester GPA and interest in engineering after one semester. The two classifications of interest (rows in the framework) are “equally or more interested in a field other than engineering” (low) and “more interested in engineering than any other field” (high). These interest categories were chosen as meaningfully distinct from each other since the analyses showed no difference in probability of being retained for students with high or very high interest, but a significant difference between very high and very low, low and medium interest.

Using a mean split approach, the two (column) classifications of GPA are below average (low) and above average (high). To establish the rationale for this approach of generating useful GPA categories for this framework, we first examined the logistic regression model to confirm that there was a significant relationship between GPA and the likelihood of being retained. However, since GPA was treated as a continuous variable in the logistic regression model, those results did not give a clear GPA threshold value for meaningfully distinguishing between high and low performance for the engineering retention framework. We considered using 3.0 based on the use of a 3.0 as a minimum GPA to maintain many scholarships^{15,44}, and the use of 3.0 as a interview minimum by many employers⁴⁵. We also considered using a unique value for each student based on their own definition of the GPA they considered a success, but this was ruled out since it would most likely not be available to other colleges using the framework. We considered using a 2.7 (B-) since this is the lowest value that still represents a B average. In the end for this analysis, we decided to use the cohort average (2.71) which was very close to a B-, although other cut-off values might be meaningful for other users of the framework. The quadrants produce a characterization of students as Stars (high interest, high GPA), Searchers (high GPA, low interest), Strugglers (high interest, low GPA) and Step-outs (low interest, low GPA) – see Figure 1. The labels given to students who fall in each quadrant were generated to capture the essential feature of each particular combination of interest and performance.

Figure 1 shows the number and percentage of students from the 2012 cohort in each of the four quadrants of the retention framework: Stars, Searchers, Strugglers, and Step-outs. Also shown are the percentage of the students within the quadrant who were retained, switched out of engineering or left the university.

		GPA	
		Below average (Low)	Above average (High)
Interest	Low Equal or more interested in another field (Low)	STEP-OUTS ($n = 38, 11\%$) Retained 21% Switched units 29% Left university 50%	SEARCHER ($n = 36, 10\%$) Retained 67% Switched units 25% Left university 8%
	High More interested in engineering than any field (High)	STRUGGLERS ($n = 102, 29\%$) Retained 61% Switched units 15% Left university 24%	STARS ($n = 176, 50\%$) Retained 94% Switched units 3% Left university 2%

Figure 1. Step-outs to Stars engineering retention framework

Quadrants in the Framework

Stars. In the framework, the students in the quadrant with high GPA and high interest were named the Stars. Based on the odds ratio from the model, the Stars would be expected to have the highest retention rate. The actual first year retention rate for the students from the 2012 cohort in this quadrant was 94%, which was the highest of all the quadrants. Based on the simplicity of the framework and the exclusion of factors such as finances and commitment to the university, the accuracy of prediction in this quadrant was high. It was not surprising that these students had the highest retention rate as they seem to have found a good fit between interest and ability. Fifty percent of the students in the 2012 cohort were in this quadrant.

At the start of the semester, 21% of the Stars indicated they had very high interest in engineering and the percentage increased to 27% at the end of the semester. Post hoc analysis, using the chi square goodness of fit test and all response categories to the question on interest, showed a significant positive change in interest for the Stars ($\chi^2(3)=12.12, p = .007$) from the first week of the semester to week 13.

Step-outs. The students in the opposite quadrant with low GPA and low interest, referred to as the Step-outs, would be predicted to have the lowest retention rate based on the logistic regression results. This group represented 11% of the 2012 cohort and their retention rate of 21% was the lowest of any quadrant. Half of the Step-outs left the university and 29% switched to another unit.

The Step-outs had a significant change in their responses to the interest in engineering question from the week 1 survey to the week 13 survey ($\chi^2(3)=429.27, p < .001$). On the week 1 survey, 76% of the Step-outs selected a higher interest category than they did on the week 13 survey. It is unknown if the students in this quadrant chose engineering as a major not knowing much about the field or the curriculum, if they lost interest due to their lackluster performance, or if their interest changed for some other reason. Future research could be conducted to determine the reasons that these students chose to study engineering and if better career advising could have helped them make a better decision that was more related to their interest and abilities. It would also be interesting to determine if their poor performance affected their interest level in engineering.

Searchers. Based on the logistic regression model, the two remaining quadrants, one characterized by high GPA and low interest (Searchers) and the other characterized by low GPA and high interest (Strugglers), would be the hardest to predict since the variables suggest opposite relationships with the likelihood of being retained in engineering. The Searchers (10% of students) had the second-highest retention rate and the highest rate of switching to other units. Based on their responses to the interest question of the week 1-survey, 57% of the Searchers indicated a higher level of interest in engineering at the start of the semester than in week 13 of the same semester. Their shift in interest was significant ($\chi^2(3)=59.96, p < .001$).

The Searchers have the ability to do above-average work in engineering, but might not be interested enough to continue to study engineering. The Searchers would likely benefit from career advising or activities that help them maintain interest in engineering. Future research could investigate if students from this group switch units later in their studies. Another interesting study would be to investigate the reasons these students indicated lower interest levels at the end of the semester than at the beginning, considering they were performing above-average.

Strugglers. The third highest retention rate was for students with low GPA and high interest. The Strugglers represented 29% of the 2012 cohort. The percent of students in this

group who left the university was less than half the percent of Step-outs who left (low interest, low GPA), even though their average GPA was not statistically different, $t(138) = 1.365, p = .171$. The percent of this group that switched to another unit was 46% less than the percent of the Searchers who switched units.

At the beginning of the semester, 30% of the Strugglers indicated they had very high interest in engineering. At the end of the semester, the percentage had increased slightly to 33%, which was higher than the percentage of Stars that had indicated they had very high interest. The data did not show a significant shift in interest between the beginning and the end of the semester for the Strugglers ($\chi^2(3)=4.33, p = .228$).

The Strugglers may benefit the most from tutoring and mentoring. Future research should investigate Strugglers to determine what factors contributed to their low performance. Further, it should be studied as to whether their high interest will enable them to persist and be successful, or whether they ultimately cannot complete their studies.

Example Analyzing Gender within the Step-outs to Stars Engineering Retention Framework

To demonstrate the benefit of characterizing students using the Step-outs to Stars Engineering Retention Framework, we investigated the variable of gender within the framework. *Figure 2* shows for each quadrant of the framework the number and percentage of males and females who were retained in engineering, switched out of engineering but remained at the university, or left the university. The percentages of females in each quadrant were representative of the percentage of females who participated in the study (22%), except in the Searcher quadrant where 36% percent of the Searchers were female.

The female Stars had the same retention rate as the male Stars and the female Strugglers and Step-outs had similar retention rates as their male counterparts (caution there were only eight female Step-outs). This was not true for the Searchers where the retention rate for males was 32% higher than for females.

Although caution must be taken when viewing these results due to the low number of female students in certain quadrants, placing the variable gender within the framework appears to indicate that female students with equal or more interest in a field other than engineering (low interest) and above average GPAs (high GPA) are more likely to switch out of engineering than males in the same quadrant, whereas the other 3 quadrants had similar percentages of retention of both males and females. If this sample is representative of other cohorts, this could help explain why some cohorts have lower retention rates for female students; it appears that female “interest” among high-performing students is a key difference between retention for males and females. These results could help identify areas to target to help increase female retention.

STEP-OUTS			SEARCHER		
	M (30)	F (8)		M (23)	F (13)
Retained	20%	25%	Retained	78%	46%
Switched units	30%	25%	Switched units	13%	46%
Left university	50%	50%	Left university	9%	8%

STRUGGLERS			STARS		
	M (79)	F (23)		M (141)	F (35)
Retained	63%	52%	Retained	94%	94%
Switched units	14%	17%	Switched units	3%	6%
Left university	23%	30%	Left university	3%	0%

Figure 2. Step-outs to Stars engineering retention framework for males and females

Conclusion

The Step-outs to Stars engineering retention framework, is a parsimonious framework based on two relatively simple variables to acquire, early performance and student's interest in engineering compared to other fields. We propose it can be a valuable framework for other studies in engineering retention and possibly other demanding fields of study. Since academic performance and interest are the top reasons students switch out of engineering^{20,21}, investigation of other factors related to retention could be viewed relative to the student's characterization in this framework. For example, by viewing gender with respect to the framework, it quickly became obvious that in this cohort a disproportionate number of the Searchers were female and the discrepancy in the retention rate between males and females was due to the number of students in the Searchers quadrant.

The interest/GPA characterization appears to be a useful grain size – not excessive number of categories, but nevertheless meaningfully distinct – to situate explorations of other variables in a more nuanced manner that permits more systematic and targeted decisions to be made to help individual students be more successful. Viewing other factors through the lens of this framework might help explain some of the inconsistencies found in the previous research on engineering retention (see Zhang et al.⁴⁶ for an example). Examples of factors that could be investigated with respect to the framework include: ethnicity, self-esteem, social integration into engineering, what influenced students to study engineering, time spent on classwork and studying, student participation in high school activities related to engineering, when students became interested in engineering, and beliefs on effort and intelligence. By investigating these factors within the framework, researchers could start to develop profiles of the students in each

quadrant. Though these profiles might vary with institution, they might enable advisors and counselors to better understand their student populations.

As colleges of engineering work to increase their retention and graduation rates, and government agencies, universities, corporations, and other organizations work to ensure an adequate supply of engineers to meet the demands of the workforce, these refined quadrants could then be used to help determine the best allocation of resources targeted to improving retention. For example, resources could be directed towards the Strugglers by offering tutoring or supplemental instruction since low GPA seems to be the variable holding them back. Based on the participants in this study, this could impact around 30% of the students. Resources could be directed toward the Stars, about 50% of the students in this study, by creating more opportunities for them to develop their interest and continue to excel, but that decision would have to be made with the foreknowledge that these students are very likely to be retained anyway, and so expenditure of resources on this group would be for other purposes, such as quality or depth of experiences rather than for retention purposes. Or resources could be directed toward the Step-outs and the Searchers, each representing around 10%, by investigating ways to increase interest in engineering or providing more opportunities to learn about engineering and the engineering curriculum before deciding to study engineering.

If characteristics of students who fall into each quadrant were more clearly identified, the framework could also be of value to students considering engineering as a college major. The more students know about the skills and personal characteristics of successful engineering students, the better equipped they will be to make their college major choice.

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