Understanding Student Retention in Engineering

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Abstract

The Academy of Engineering Success (AcES) program employs known best practices to support engineering students with the goal of retaining them through graduation and diversifying the engineering workforce. The AcES program started in 2012 and has been supported by NSF S-STEM award number DUE-1644119 since 2016. Cohorts from 2016, 2017, 2018, and 2019 consist of 12, 20, 22, and 17 students, respectively. Twenty-one renewable S-STEM supported scholarships have been awarded to students since 2016.

AcES students participate in a one-week pre-fall bridge experience, a common fall professional development course, and a course emphasizing the role of engineers in societal development in the spring semester. Starting in the bridge experience and continuing until graduation, students participate in curricular and co-curricular activities with the goals of: (1) fostering feelings of belonging in engineering and institutional inclusion, (2) encouraging professional development, and (3) supporting academic achievement and student success. These goals are achieved by providing: (1) opportunities for interaction between students and peers, faculty, and industry mentors; (2) major and career exploration opportunities; and (3) academic support and student success education in areas such as time management and study skills.

AcES students participate in the GRIT, LAESE, and MSLQ surveys, as well as in focus groups and one-on-one interviews at the start and end of each fall semester and at the end of the spring semester. The surveys provide a quantitative measure of students' GRIT, general self-efficacy, engineering self-efficacy, test anxiety, math outcome efficacy, intrinsic value of learning, inclusion, career expectations, and coping efficacy. Qualitative data from the focus group and individual interview responses are used to provide insight into the quantitative survey results.

Surprisingly, a previous analysis of the 2017 cohort survey responses revealed that students who left engineering had higher baseline values of GRIT, career expectations, engineering self-efficacy, and math outcome efficacy than those students who retained. Hence, the 2018 cohort survey responses were analyzed in relation to retention and are presented along with qualitative results to provide a holistic understanding of student retention. Results from both the 2017 and 2018 cohorts are presented and discussed in the paper and poster.

1.0 Introduction

The AcES Program is an NSF S-STEM supported program that aims to increase the number of students from traditionally underrepresented groups who pursue undergraduate degrees in engineering by supporting and retaining students in engineering. Support is provided both academically through a variety of academic support resources and financially by providing merit-based scholarships to qualifying academically talented, low-income students in the program. One objective of this program is to increase graduation rates from underrepresented populations, including women, first-generation students, and underrepresented minorities in an effort to diversify the engineering workforce.

This paper reviews characteristics of the AcES program and presents a new analysis of a previously identified trend in an ongoing study of program participants. An earlier analysis of survey results of the 2017 program cohort appeared to support the Kruger-Dunning Effect, a cognitive bias in which unskilled people do not recognize their incompetence in specific areas and often overestimate their abilities [1]. Based on the survey results from the beginning of their first semester of engineering school, students who ultimately left engineering before their second year had higher scores in grit, career expectations, engineering self-efficacy, and math outcome efficacy that those students who retained in engineering. This paper explores this apparent trend more deeply by presenting the subsequent analysis of both the 2017 and 2018 AcES program cohorts along with insight gained through qualitative data also collected from these cohorts.

2.0 Program Description

The cohort-based AcES program, initially implemented in 2012, employs known best practices to support and retain students from populations underrepresented in engineering to attempt to increase the number of high-achieving, low income students from these populations who pursue, persist, and ultimately graduate with engineering degrees [2]. A variety of activities and services are provided to help students develop feelings of inclusion, engineering identity, and academic and professional success skills that will help them retain and persist in college and also help them succeed professionally as an engineer. The program attempts to facilitate a feeling of institutional inclusion and the development of an engineering identity by providing opportunities for faculty-student and student-student interaction in a variety of settings. Academic support is provided through tutoring services, academic advising, and the development of broader student success skills, such as time management, learning strategies, technical communication, teamwork, and networking skills. Professional development activities include engineering research lab tours, guest speakers, and industrial site visits [2]. Beginning in 2016, NSF S-STEM funded merit-based scholarships were made available to eligible low-income AcES students. The 21 students who receive the NSF S-STEM scholarship must remain enrolled in the engineering college and maintain a cumulative GPA of 3.0 or higher for annual scholarship renewal.

Since 2012, the program creators have experimented with a variety of formats, from longer summer bridge components to different content and structure in the fall professional development course and varying cohort sizes. Currently, the AcES program has an annual enrollment of 20 first-time, full-time (FTFT) engineering students and consists of: a one week summer bridge experience directly prior to the beginning of the fall term; a two credit-hour professional development course in the fall; a three credit-hour general education “Engineering in History” course in the spring to show how engineers have shaped society throughout history; a mentor program including both student and industry mentors; social events engaging all cohorts; and scholarship opportunities. Cohort building, academic skill development, career guidance, and the creation of a personal and academic support system are main goals of the program.

All engineering students at West Virginia University WVU) start in a common first-year program and complete a set of core courses before moving to their declared engineering discipline major. AcES students are advised by a program faculty mentor until they meet the requirements to move into their desired engineering discipline.

3.0 Methodology

At the beginning of each fall term and at the end of each spring term, program participants complete three surveys to measure various characteristics thought to indicate level of retention and persistence within engineering. These surveys are: the 12-question GRIT survey, a modified 31- question version of the Longitudinal Assessment of Engineering Self-Efficacy (LAESE) survey, and a 44-question version of the Motivated Strategies for Learning Questionnaire (MSLQ). Each of these instruments is explained below.

"Grit" has been defined by Dr. Angela Duckworth of the Department of Psychology at the University of Pennsylvania as "passion and sustained persistence applied toward long-term achievement, with no particular concern for rewards or recognition along the way." [3] This unique trait is measured using the GRIT survey consisting of 12, 5-point Likert scale (1 = not gritty to 5 = very gritty) questions, also developed by Dr. Duckworth [4].

The LAESE survey, originally created via the NSF-funded Assessing Women in Engineering (AWE) project [5], purports to measure traits believed to influence student retention and persistence in engineering: engineering self-efficacy, math outcomes self-efficacy, engineering career expectations, feelings of inclusion within the engineering community, and self-efficacy in coping with challenges and difficulties [5]. Based on Jordan's definition of the LAESE survey subscale calculations [6], this study uses a shorter version of the full LAESE survey consisting of 31 questions (items 16-46 on the AWE LAESE survey), including the original twenty-one 7-point Likert scale questions, plus the ten 7-point Likert scale questions asking "to what extent do you agree." The LAESE subscales include: (1) Engineering career expectations, (2) Engineering self-efficacy 1, (3) Engineering self-efficacy 2, (4) Feeling of inclusion, (5) Coping self-efficacy, and (6) Math outcomes efficacy. The two subscales measuring "engineering self-efficacy" are differentiated in what they seek to measure as follows: (1) The "Engineering self-efficacy 1" subscale measures a student's perception of his or her ability to earn an A or B in math, physics, and engineering courses and succeed in an engineering curriculum while not giving up participation in outside interests; and (2) the "Engineering self-efficacy 2" subscale measures the student's perception of his or her ability to complete (but not necessarily obtain an A or B) engineering requirements such as math, physics, chemistry as well as their general ability to succeed in any engineering major [5]. Engineering self-efficacy 1 includes a higher grade achievement belief with little disruption to life, while the engineering self-efficacy 2 focuses on completion as the measure of "success."

The 1990 MSLQ survey used in this study was created by Pintrich and DeGroot and uses 44 7-point Likert scale (1 = not at all true of me to 7 = very true of me) questions resulting in five subscales measuring traits in two main categories: motivational beliefs and learning strategies. The motivational belief category contains three subscales: intrinsic value, self-efficacy, and test anxiety; and the learning strategies category contains two subscales: strategy use and self-regulation (both are combinations of subscales in the 1991 University of Michigan version) [7,8].

Table 1, below, summarizes the three instruments used to measure characteristics of entering first-year engineering students in the AcES program. These traits are believed to be predictive of students who retain and persist in engineering programs.

Table 1: Summary of GRIT, LAESE, and MSLQ Survey Subscales [9]

Survey	Number of Questions	Likert Scale	Measures (Subscales)		
Grit	12	5-point	Grit		
LAESE	31	7-point	Engineering career expectations	Engineering self-efficacy 1	Engineering self-efficacy 2
			Feeling of Inclusion	Coping self-efficacy	Math outcomes self-efficacy
MSLQ	44	7-point	Motivational Beliefs: Intrinsic value; self-efficacy; test anxiety		
			Learning Strategies: Self-regulation; strategy use		

4.0 Results and Discussion

Results from all three surveys (GRIT, LAESE, and MSLQ) for the 2017 and 2018 program cohorts are presented and discussed below. Twenty students completed the surveys in fall 2017 and 22 students completed the surveys in fall 2018. Fifteen of the 20 students in the 2017 cohort were retained in engineering to the second year, while five students left engineering. Of the 22 students in the 2018 cohort, 14 retained in engineering to the second year while eight students left engineering. Their average scores on the survey measures, presented in Table 2 below, provide interesting insight to the initial attitudes and beliefs of these novice engineering students. For each sub-score or measure presented in Table 2, the higher value is highlighted in gold to aid in identifying trends and interpreting results.

Table 2: Summary of 2017 and 2018 Cohort Results from GRIT, LAESE, and MSLQ Surveys

Survey Instrument & Characteristic Measure	**Fall 2017 Cohort (n=20)**		**Fall 2018 Cohort (n=22)**		**Combined Data (n=42)**	
	Retained (n=15)	**Left ENGR (n=5)**	**Retained (n=14)**	**Left ENGR (n=8)**	**Retained (n=29)**	**Left ENGR (n=13)**
GRIT (Likert scale: 1 = low; 5 = high)	3.49	3.97	3.51	3.21	3.50	3.50
LAESE (Likert scale: 1 = low; 7 = high)						
Engineering career expectations	6.60	6.67	6.74	6.33	6.67	6.46
Engineering self-efficacy 1	5.87	6.87	5.98	5.83	5.92	6.23
Engineering self-efficacy 2	6.37	6.78	6.64	6.39	6.50	6.54
Math outcomes self-efficacy	6.29	6.89	6.54	6.22	6.41	6.48
Coping self-efficacy	6.49	6.44	6.51	6.42	6.50	6.43
Feeling of inclusion	5.48	5.00	5.75	5.75	5.56	5.46
MSLQ (Likert scale: 1 = low; 7 = high)						
Motivational Belief: Intrinsic value	5.79	4.56	5.83	5.62	5.81	5.21
Motivational Belief: Self-efficacy	5.61	5.15	5.69	5.75	5.65	5.52
Motivational Belief: Test anxiety	3.59	3.67	4.63	4.53	4.09	4.20
Learning Strategy: Self-regulation	5.11	4.37	4.68	4.88	4.90	4.68
Learning Strategy: Strategy use	5.14	4.18	5.31	5.18	5.22	4.80

Not surprisingly, students in both cohorts who retained in engineering scored higher in three attributes: (1) coping self-efficacy, (2) a belief in the intrinsic value of studying engineering and (3) learning strategy use. Of these three measures, the largest average score difference (0.60) between students who retained versus students who left engineering was the motivational belief in the intrinsic value of the study of engineering, with retained students having an average score of 5.81 and students who left engineering having an average score of 5.21. Qualitative data gleaned from the focus groups and one-on-one interviews appear to support this result. First-year engineering students cited an interest in STEM and the perceived hands-on nature of engineering as reasons they decided to pursue engineering as a college major and career [10]. As students progressed in their engineering studies, they began to mention the philanthropic nature of engineering (helping others, making a difference in the world) as motivational to their pursuit of an engineering career. While the first-year program emphasizes the value of engineering to society, the students in the AcES program take an entire course focusing on the societal value of engineering.

Strategy use had the second highest difference (0.42 points) in average scores between students who retained and students who left engineering, with retaining students scoring an average of 5.22 and leaving students scoring an average of 4.80. Coping self-efficacy was third, with the small difference of 0.07 points between the average score of retained students (6.50) and the average score of students who left engineering by the second year (6.43).

In the 2018 cohort, the average feeling of inclusion score was the same for both students who retained and students who left engineering by the second year, but the score, 5.75, was higher than those who retained in engineering in the 2017 cohort. The combined data indicates that students who retained in engineering scored 0.10 points higher on the measure of feeling of inclusion (5.56) than students who left engineering (5.46). The data suggests that feeling of inclusion may also be a predictor of student retention in engineering. Surprisingly, there were no common traits of students who left engineering before their second year.

Interestingly, 2017 students who left engineering had several “stronger” traits in common with 2018 students who retained in engineering. Those traits include scoring higher in: Grit, as measured by the Grit survey; engineering career expectations, engineering self-efficacy 1, and engineering self-efficacy 2, as measured by the LAESE survey; and test anxiety, as measured by the MSLQ survey. Only 2 traits measured by the MSLQ were scored higher by both 2017 students who retained and 2018 students who left engineering by the second year; those traits were: (1) the motivational belief of self-efficacy and (2) the learning strategy of self-regulation.

Due to small cohort sizes and small number of students leaving, the differences in subscale scores between students who retained and students who left engineering for each subscale are statistically insignificant. Additional data is needed. An interesting trend, however, appears to emerge. Students who start their engineering studies with a higher belief in the intrinsic value of studying engineering and a higher measure of strategy use, as well as a higher coping self-efficacy, appear to retain past their first year more than those students with lower scores in these three areas.

There is a significant difference (0.05 level of significance) between the first-year retention rate of the 2017 cohort (75%) and the first-year retention rate of the 2018 cohort (64%). Those retained in the 2017 cohort scored highest in the areas of: (1) Engineering career expectations (6.60); (2) Coping self-efficacy (6.49); (3) Engineering self-efficacy 1 (6.37); and (4) Math outcomes self-efficacy (6.29). Three of these four measures, however, were actually higher for the 2017 students who left engineering; only coping self-efficacy was higher for retained students (6.49) than for leaving students (6.44). The top four measures for 2018 retained students were all higher than for the 2018 students who left engineering, and they include: (1) Engineering career expectations (6.74); (2) Engineering self-efficacy 2; (3) Feeling of inclusion (6.54); and (4) Coping self-efficacy (6.51).

An examination of the combined 2017 and 2018 cohort data shows the top two measures for retained students are: (1) Engineering career expectations (6.67) and (2) Coping self-efficacy (6.50). Students who left engineering, however, scored higher in the areas of engineering self-efficacy 1 (6.23), engineering self-efficacy 2 (6.54), math outcomes self-efficacy (6.48), and test anxiety (4.20) than their peers who retained in engineering. This result from the combined data supports the Kruger-Dunning Effect in that it appears that the students who ultimately leave engineering before the second year, start in engineering with an unrealistic view of the difficulty of the field or an overestimation of their ability to succeed. These students believe they will succeed in engineering and math, but also have higher test anxiety scores than their counterparts who retain in engineering.

5.0 Conclusions and Recommendations

While the 2017 cohort data appears to support the Kruger-Dunning Effect, the 2018 cohort data does not. When combined, however, the data again supports the Kruger-Dunning Effect. The trends show that those who leave engineering before the start of their second year have higher initial scores in Engineering self-efficacy 1 and Engineering self-efficacy 2, indicating that they may have an unrealistically high expectation for their success in engineering. Additionally, students who left engineering also scored higher in test anxiety, overall, than those who stayed in engineering.

The fall 2018 cohort data, however, indicates very different trends. First, the retention rate is significantly different between the fall 2017 and the fall 2018 cohorts. Second, those students in the fall 2018 cohort who left engineering before the start of the second year scored higher in only two categories, general self-efficacy and self-regulation, than their peers who retained to the second year. These students apparently viewed themselves more realistically, but assessed their situations and changed their majors away from engineering. The 2018 cohort students who retained in engineering through their first year showed higher grit, engineering self-efficacy, math outcomes efficacy, and engineering career expectations then their peers who left engineering. In the 2018 cohort, the feelings of inclusion score is the same for students who retained in engineering and those who left engineering.

Retained students in both cohorts (and in the combined data group) had higher scores in three measures: (1) the (motivational) belief in the intrinsic value of engineering; (2) learning strategy use; and (3) coping self-efficacy. It appears that students who retain in engineering start their

journey with motivation and the ability to meet challenges and solve problems while maintaining their belief in the value of the profession.

Test anxiety appears to be increasing, in general, between the 2017 and 2018 cohorts, from 3.59 for retained students and 3.67 for students who left engineering from the fall 2017 cohort to 4.63 for retained students and 4.53 for students who left engineering from the fall 2018 cohort. Interestingly, however, in the 2017 cohort, those students with the higher test anxiety score left engineering, while in the 2018 cohort those students with the higher test anxiety score retained and their test anxiety scores was 1.04 (out of 7) points higher than the 2017 retained students and 0.96 points higher than 2017 students who left. The combined data indicates that, in general, students with the higher test anxiety scores (4.20) left engineering.

The combined data of the 2017 and 2018 cohorts supports the Kruger-Dunning Effect, even though, separately, these two cohorts provide contradictory results: the 2017 cohort data supports the Kruger-Dunning Effect, while the 2018 cohort data does not. Additional data and analysis are needed to determine the prevalence of this effect in first-year engineering students.

6.0 Future Work

Data collection and analysis will continue with the fall 2019 cohort to further study trends in self-reported measures of grit, self-efficacy, career expectations, feelings of inclusion, motivational beliefs, and learning strategies and their relation to student retention and persistence to graduation. Scholarship recipients also participate in focus groups and one-on-one interviews and that data is being analyzed with the goal of gaining a holistic understanding of student retention and finding trends in longitudinal change in students' perceptions of the engineering profession as well as in their motivation and persistence.

This material is based upon work supported by the National Science Foundation under Grant No. DUE-1644119. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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