Creativity as a Factor in Persistence and Academic Achievement of Engineering Undergraduates

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Abstract

Background To date, there has been little research to establish how creativity relates to engineering student persistence and academic achievement.

Purpose This study used creativity to predict engineering student persistence and achievement relative to demographics, academic aptitude, and personality. It further evaluated those predictors for consistency throughout the undergraduate engineering program.

Design/Method Participants were entering first-year engineering students in 2011 and 2012. Academic aptitude was measured by high school rank and SAT scores. Personality was characterized using the Big Five inventory, which measures the traits of Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness. Creativity was assessed using student artifacts on three tasks and a modified creativity questionnaire. Outcome measures were students' persistence and GPA over four years. Multinomic logistic regression and multivariate regression were used to model the relationship between predictor variables and persistence and achievement.

Results SAT math, high school rank, and Conscientiousness were predictors of persistence and achievement. Creativity measures did not predict GPA, and creative self-efficacy was negatively related to engineering student persistence in the major.

Conclusions Our results suggest that creativity is not appropriately taught or rewarded in some engineering curricula, and those engineering students who view themselves as highly creative are less likely to graduate in engineering.

Keywords creativity; persistence; achievement; regression

Introduction

The call for innovative engineers is universal and timely. The need for creative problem solvers is increasingly emphasized among the problems facing society. The National Academies and political leaders have called for innovative engineers to drive the engine of America's economy (National Governors Association, 2007; Perry et al., 2008), yet the decline of American students' math and science test scores relative to those of other countries casts doubt on our ability to remain world leaders in technology. The strength of the American education system is often said to be our encouragement of creativity (Provasnik et al., 2012). Creativity has been at the forefront of the definition of "genius" – a person who can revolutionize industries, stimulate

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demand for products that didn't previously exist, and keep America's economy robust (Cornelissen, 2013; Steinwart & Ziegler, 2014).

The field of engineering education is starting to incorporate the concept of creativity into its vocabulary to reflect its importance in engineering problem solving and design. Research studies are characterizing creative engineers (Ferguson & Ohland, 2012) and developing approaches that systematically enhance creativity in engineering students during their years in an engineering program; such approaches include innovative teaching techniques (Brent & Felder, 2014; Daly, Mosyjowski, & Seifert, 2014), heuristics for creative design (Daly, Yilmaz, Christian, Seifert, & Gonzalez, 2012), and makerspaces to encourage new ideas (Halverson & Sheridan, 2014).

Psychologists define creativity as the production of ideas that are both novel and useful or appropriate (Sternberg & Lubart, 1995). In contrast, innovation emphasizes the importance of the practicality of the new idea (Cropley, 2015b). According to the investment theory of creativity (Sternberg & Lubart, 1995), creativity requires a combination of many cognitive and noncognitive factors, including intelligence, knowledge, thinking style, personality, motivation, and the environment. Intelligence serves creativity by helping to identify new problems and recognize which solutions are good ones. Knowledge is required to make sure that an idea is truly new in the context of the domain. Thinking styles are not an ability but rather the tendency to use one's abilities to devise new ideas. Creativity also depends on a personality that is open to new experiences, tolerates ambiguity, and takes risks. Motivation is the drive to create even in the face of significant adversity. Finally, creative work is fostered by an environment that allows and rewards new ideas. In our work, we considered several of these factors along with creativity itself in predicting academic achievement in engineering students. Specifically, we approximated intelligence by using standardized test scores and measured personality using a standard assessment of the Big Five personality traits

There has been little research to establish how creativity relates to engineering student persistence and achievement in a traditional, ABET-accredited engineering curriculum. This study fills a gap in the literature by examining creativity measures, personality characteristics, demographics, and academic aptitude as factors in engineering student persistence and achievement. Moreover, this study is one of only a few to consider both engineering student persistence *and* academic achievement of the same cohort, beyond the first year.

Literature Review

A number of studies have predicted engineering student academic achievement and persistence using a variety of factors. These have commonly included demographic and background characteristics, standardized test scores, high school performance, and gateway course scores. The two variables that most consistently predict engineering student persistence and achievement are the Scholastic Aptitude Test (SAT) math score and high school performance as measured by grade point average (GPA) or rank (Astin & Astin, 1992; Besterfield-Sacre, Atman, & Shuman, 1997; French, Immekus, & Oakes, 2005; Hall et al., 2015; Kamphorst, Adriaan Hofman, Jansen, & Terlouw, 2015; Mendez, Buskirk, Lohr, & Haag, 2008; Veenstra, Dey, & Herrin, 2008, 2009; Zhang, Anderson, Ohland, & Thorndyke, 2004).

Personality traits have also been examined in relation to persistence and academic achievement. Hall et al. (2015) found that in addition to SAT math, high school GPA, and a math placement score, the only significant personality trait to predict persistence of engineering students was Conscientiousness. Conscientiousness also predicts academic achievement in college (O'Connor & Paunonen, 2007), and this effect has been found to be strongest among science majors (Vedel, Thomsen, & Larsen, 2015).

The relationship between creativity and academic achievement has been a subject of recent study in educational psychology, with conflicting results. Several studies have found that creativity has a mild but positive relationship with high school academic achievement (Grigorenko et al., 2009; Niaz, Nunez, & Pineda, 2000) and with standardized test scores (Dollinger, 2011). Others have found a negative relationship or no relationship at all between creativity and academic achievement (Blake, McCarthy, & Krause, 2014; Boulter, 2002; Furnham, Zhang, & Chamorro-Premuzic, 2005). A recent study of undergraduate students showed mild positive relationships between standardized test scores and creative performance; yet, at the same time, high school rank was negatively related to self-reported creative ability (Pretz & Kaufman, 2015). This finding may be due to the fact that high school grades do not reward creativity, but it may also suggest that the academically strongest students were less confident in their ability to be creative.

The mixed findings regarding creativity and academic achievement may be due in part to an unclear understanding of how much institutions of higher education encourage and reward creativity in students. A recent study by Daly, Mosyjowski, and Seifert (2014) found that most educational programs do not deliberately evaluate academic work on the basis of creativity. Critical thinking is a more common goal of higher education, but some researchers see creative thinking as a component of critical thinking. For example, Halpern (2013) has argued that critical thinking includes problem solving and brainstorming solutions, both of which involve creativity.

Veenstra, Dey, and Herrin (2008) presented a comprehensive review of the literature up to 2008 comparing factors that predict achievement for both engineering students and nonengineering students, which was updated by Hall et al. (2015). Creativity has not been previously considered as a factor to predict engineering student persistence or achievement.

Research Questions

Academic aptitude factors such as SAT math and high school performance are well-established predictors of engineering student persistence and academic achievement; prior work has also examined individual difference factors such as personality. Creativity has not been similarly explored as a predictor. Studies relating creativity and academic achievement in higher education have produced inconsistent results, and work has not focused intensively on engineering students. This lack of prior research combined with the emphasis on creativity in the field of engineering motivated our desire to understand how creativity relates to the persistence and achievement of engineering students.

Our study attempted to show how creativity is uniquely related to academic achievement, independent of the effects of potential confounding variables such as standardized test scores and personality traits. With this motivation and existing literature in mind, we had two research questions:

> Can creativity predict engineering student persistence (as indicated by remaining in the major) and achievement (as indicated by college GPA) relative to demographics, academic aptitude, and personality? That is, do individual differences in creativity help us predict student persistence and achievement better than if we make predictions based on demographics, academic achievement, and personality alone?
>
> Are predictors of persistence and achievement consistent throughout the duration of the undergraduate engineering program?

This study is a first step in determining if and when traditional engineering curricula are retaining or driving away highly creative students. We hypothesized that student persistence and achievement will be predicted by SAT math, high school rank, and Conscientiousness, and that the addition of creativity will significantly improve our ability to predict these outcomes. We also predicted that SAT math and high school rank would be more important predictors of early student achievement, while creativity would increase in significance in later years as students experience courses with fewer "right answers" and more open-ended design opportunities. Evaluating whether creativity measures predict engineering student achievement relative to SAT scores and high school rank may also help determine the degree to which creativity plays a part in successful student problem solving and design in one traditional engineering curriculum.

Method

Participants

To answer these research questions, we focused on two cohorts of entering engineering students at Elizabethtown College – a small, private, liberal arts college in the Mid-Atlantic region of the United States with ABET-accredited programs in general engineering and computer engineering. The dataset included any student in the 2015 (entered 2011) and 2016 (entered 2012) cohort who took Introduction to Engineering I during their first two years (most during their first semester) and indicated an intended major of engineering. The sample contains 45 students in the 2015 cohort and 40 students in the 2016 cohort, with a total of 72 men and 13 women. After the first two semesters, 64 of the original 85 students remained in the engineering major (75%) as indicated by their enrollment in engineering courses in the third semester. By the time the students either graduated or enrolled in engineering courses in their final year, 56 students remained (66%). These retention rates are comparable to national data for similar programs with no additional screening for engineering admission, with 78% persisting to the second year and 61.3% persisting to the fourth year (Yoder, 2016).

Materials and Procedure

During the students' first semester, in the context of a class activity in a required introduction to engineering course, the students took a 30-minute online assessment of personality and general creativity. Personality traits were estimated using 50 items from the International Personality Item Pool (Goldberg et al., 2006) designed to measure the Big Five personality traits (10 items per trait): Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness.

General creativity was assessed using student artifacts and a modified creativity questionnaire that are very similar to those commonly used in the psychological literature on creativity (Plucker & Makel, 2010). First, students completed a divergent thinking task in which they brainstormed ideas for using a $1 million donation to the college. Students indicated their top two responses on the divergent thinking task, and both of those ideas were rated for creativity. Second, students were asked to write a caption for an ambiguous photograph such as a middle-aged man seated at a desk surrounded by notebooks. Third, students were prompted to write a brief essay describing their dream project in their major field of study. Each of these responses was rated by six undergraduate psychology or engineering majors trained in the Consensual Assessment Technique (Amabile, 1996). In previous work, the use of undergraduates as raters in creativity studies has been shown to produce highly reliable ratings that are quite similar to those of experts, especially for products that are in nonspecialist domains such as those used in this study (Kaufman, Baer,

& Cole, 2009). Raters scored each divergent thinking idea, each caption, and each essay for creativity on a scale from 1 (not at all creative) to 6 (highly creative). Interrater reliabilities were calculated using the intra-class correlation coefficient (ICC; Shrout & Fleiss, 1979), and all were sufficient at 0.75 and greater.

The modified creativity questionnaire measured prior creative achievement and global creative self-efficacy using the Creative Achievement Questionnaire (CAQ; Carson, Peterson, & Higgins, 2005) and Beghetto's (2006) three-item self-reported measure on a scale of 1 to 5. The CAQ assesses the frequency of past creative achievements in 10 domains, including the arts, the sciences, and nonacademic domains such as humor and culinary arts. Participants endorsed statements about achievements in each domain. For example, items for visual arts are "I have taken lessons in this area," "People have commented on my talent in this area," "I have won a prize or prizes at a juried art show," "I have sold a piece of my work," "My work has been critiqued in local publications," and "My work has been critiqued in national publications." Responses were scored by summing the total number of statements endorsed for each domain. Total scores on the CAQ were created by summing across all domains of creative achievement and log transformed to produce a more normal distribution (Silvia, Wigert, Reiter-Palmon, & Kaufman, 2012).

Admissions information including SAT scores, high school rank, and demographic information (sex, ethnicity, and first-generation status) were retrieved from the college for all consenting students. We also obtained each student's GPA and major at the end of each academic year.

Data Analysis

Data were analyzed using R, an open source statistical programming language, and 14 supplemental statistical packages. Predictor variables were organized for analysis into four conceptual categories: demographics, academic aptitude, personality characteristics, and creativity measures. We did not include age, ethnicity, or citizenship status due to small sample sizes in the subsets (81%, 18 years old; 82%, Caucasian; 86%, U.S. citizens). There were 85 observations of 22 variables in the dataset (Appendix A). Some variables had missing values primarily because information was waived during the admissions process (e.g., there were ACT scores instead of SAT scores and no high school rank), students withdrawing from the program, or students not agreeing to release their admissions or college GPA data for the research study. Missing data were handled with available-case analyses.

Results

We first used a series of t-tests on all measures to determine if we could treat the two cohorts of students as drawn from a single population. Significant differences at $p < 0.05$ were size of high school, $t(83) = 2.111$, $p = 0.039$, and SAT writing, $t(83) = 2.048$, $p = 0.044$, between the two cohorts; the measure of Neuroticism, $t(83) = 2.927$, $p = 0.009$, between the sexes with women being less neurotic; and SAT math, $t(78) = 2.028$, $p = 0.046$, SAT critical reading, $t(78) = 2.311$, $p = 0.023$, and SAT writing, $t(78) = 2.678$, $p = 0.009$, between the first-generation and non–first-generation students, with first-generation students having slightly lower SAT scores. Only two of the identified factors were significant at $p < 0.01$, so we considered the students as drawn from one sample for the analysis, but kept these factor variables as predictors in the regression models. They did not reach the level of significance, so they were not retained. The mean, median, and standard deviation for each of the numeric variables are shown in Table 1.

Table 1 Descriptive Statistics for the Numeric Variables

Variable	*n*	*M*	*Mdn*	*SD*
Demographic				
High school size	61	288.6	290	152.3
Academic aptitude				
SAT math	77	600.5	600	71.5
SAT critical reading	77	547.3	560	68.7
SAT writing	77	528.4	520	80.0
High school rank	55	75.9	51	18.0
Personality measures				
Extraversion	85	3.19	3.1	0.82
Agreeableness	85	3.82	3.9	0.61
Conscientiousness	85	3.41	3.4	0.61
Neuroticism	85	3.47	3.3	0.72
Openness	85	3.60	3.6	0.60
Creativity Measures				
Creative self-efficacy	85	3.88	4.00	0.88
Creative achievement	85	0.83	0.85	0.29
Caption creativity	85	3.07	3.12	1.11
Essay creativity	85	3.00	2.97	0.91
Divergent thinking	83	2.96	2.94	0.79
Achievement outcome measure				
First-year GPA	77	2.96	3.03	0.62
Final-year GPA	55	3.16	3.18	0.44

Descriptive Statistics

SAT score distributions were reasonably symmetrical with math scores slightly higher than writing and critical reading, as expected. A few outliers were present, but all data were retained. The eight missing observations indicate students who likely did not release their SAT scores, provided ACT total scores, or were not required to provide scores during the admissions process. The Big Five personality traits were normally distributed along the entire 5-point scale, with no outliers. There were no major differences by cohort or sex. Because the number of women ($n = 13$) was small, they are grouped with the men for the regression analysis.

Students' self-reported creativity was slightly skewed towards higher scores with a mean of 3.88 and median of 4.0 out of 5, while their rated creativity measures were a bit lower on average, around 3.0. Resulting t-tests on creativity measures comparing sexes and cohorts found no significant differences. The log transform of the Creative Achievement Questionnaire summary score put this variable on a difference scale, but successfully transformed the data to a normal distribution.

The overall retention rate of the student sample was 66% (Table 2). A slightly higher persistence was observed with the 2015 cohort, among women, and among the non–first-generation students (who also had slightly higher SAT scores). Overall, since the retention rates were comparable, we were justified in combining all the data for statistical power. There were no missing observations of persistence.

Table 2 Student Persistence

	Students entering program	Students persisting to final year	Persistence (%)
Overall	85	56	66
Leaving in first-year	85	64	75
Leaving in later years	64	56	88
2015 cohort	45	31	69
2016 cohort	40	25	61
Men	72	47	65
Women	13	9	69
First generation	40	24	60
Not first generation	40	28	70

GPA distributions were reasonably symmetrical with no outliers. Scores covered a large range from less than 2.0 (academic probation) to close to 4.0 on a 4-point scale, with a mean and median of approximately 3.0. The final-year GPA is defined as the graduation GPA for the 2015 cohort, and the starting fourth-year GPA for the 2016 cohort. The narrowing GPA distribution in later years reflects the fact that students with lower GPAs switch out of the major or college or are forced to leave if their GPA is below 2.0. Both cohorts, sexes, and first-generation students had similar GPA distributions. A total of eight observations are missing for the first-year GPAs and 30 for the final year; these represent students who did not release their data or did not persist.

Correlations

As expected, SAT scores correlated with one another, as well as with the outcome variables pertaining to first-year and final-year GPA, and first-year and final-year persistence (Table 3). Creative self-efficacy was the lone creativity measure correlated with student outcomes and had a negative relationship with final-year persistence. Conscientiousness was the primary personality measure correlated with persistence and academic achievement in both the first and final years.

Over time, some relationships between the variables changed slightly. Regarding student achievement, SAT math, writing, high school rank, and Conscientiousness consistently correlated with better GPA performance. In the first year, Extraversion and Agreeableness were also negatively correlated with GPA. Persistence was consistently positively correlated with both SAT math and Conscientiousness, but during the first year, persistence was also positively related to SAT writing and high school rank.

Creativity measures showed positive correlations with SAT scores and high school rank as well, which are the most commonly used predictors of college GPA and persistence. Creative self-efficacy and the creative essay task were positively correlated with SAT writing and critical reading, respectively. However, these same two measures were negatively correlated with high school rank. As found in other studies on creativity, creative self-efficacy was also positively correlated with the Big Five personality trait of Openness.

Regression Modeling

We then performed both forward and backward hierarchical regressions to model the relationship between predictor variables and student persistence (multinomic logistic regression)

Table 3 Variable Correlations with Persistence and GPA Outcomes

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	O1	O3
1 SAT math																
2 SAT critical reading	**0.51*****															
3 SAT writing	**0.55*****	**0.63*****														
4 High school rank	0.06	−0.09	**0.29***													
5 Extraversion	−0.04	**−0.26***	−0.06	0.01												
6 Agreeableness	−0.12	−0.12	−0.03	−0.07	**0.34****											
7 Conscientiousness	−0.05	−0.20	−0.08	**0.29***	0.01	**0.24***										
8 Neuroticism	0.08	0.02	0.01	−0.10	**0.25***	0.15	0.12									
9 Openness	0.17	0.16	0.18	**−0.34***	0.21	**0.37*****	0.10	0.06								
10 Creative self-efficacy	0.16	0.20	**0.25***	**−0.26**$^{+}$	0.14	**0.40*****	0.12	0.13	**0.82*****							
11 CAQ	0.10	−0.03	0.08	−0.04	**0.23***	**0.28****	0.13	0.10	**0.42*****	**0.34****						
12 Creative caption	0.16	0.04	0.13	0.04	**0.23***	0.01	−0.14	0.07	0.13	0.06	0.08					
13 Creative essay	0.20	**0.25***	0.04	**−0.29***	−0.19	−0.04	−0.15	0.05	0.11	0.18	0.06	0.05				
14 Divergent thinking	0.15	0.07	0.03	−0.02	0.08	0.11	−0.16	**0.26***	0.16	**0.23***	0.21	0.09	0.10			
O1 First-year GPA	**0.42*****	0.21	**0.37****	**0.47*****	**−0.19**$^{+}$	**−0.23***	**0.25***	−0.02	−0.17	−0.07	−0.02	−0.03	−0.05	0.04		
O2 Final-year GPA	**0.54*****	**0.40****	**0.50*****	**0.56*****	−0.10	−0.14	**0.32***	0.16	−0.06	0.04	0.01	0.07	0.15	0.17	**0.84*****	
O3 First-year persistence	**0.30****	0.11	**0.28***	**0.28***	0.02	0.11	**0.21***	−0.11	−0.02	−0.07	0.07	−0.08	−0.04	−0.04	**0.49*****	
O4 Final-year persistence	**0.29****	0.08	0.18	0.21	−0.10	0.08	**0.20**$^{+}$	−0.10	−0.10	**−0.20**$^{+}$	−0.01	−0.11	−0.03	0.02	**0.52*****	**0.80*****

$^{+}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

and academic achievement (multivariate linear regression), in both the first year and final year. The backward regressions started with all predictors included in the model; we iteratively removed the single predictor with the highest p-value and re-evaluated the model. Variables with p-values less than 0.10 were retained. Both the literature and preliminary correlation analysis guided the order of variable addition in forward regression. For linear regression, the adjusted R^2 value was also used as a measure of goodness of fit. From these two approaches, we converged on four regression models that included only statistically significant predictors that independently assisted in explaining the variation of the outcome measures. We used these four regression models to answer our research questions.

Does creativity predict persistence in engineering? How does the role of creativity in persistence change over time? The logistic regression model to predict first-year persistence included only the statistically significant predictors SAT math, high school rank, and Conscientiousness. None of the creativity measures were significant predictors in the model for first-year persistence. The odds ratio estimates along with the 95% confidence intervals and p-values are shown in Table 4. This model was based on 53 observations of complete cases. Several goodness-of-fit measures show that this model significantly improved the fit above the intercept alone (likelihood ratio $\chi^2 = 12.64$, $p < 0.001$, Nagelkerke $R^2 = 0.323$, $p < 0.001$, Wald tests on each predictor, $p < 0.1$). This odds-ratio means that for each decile higher in high school rank, the odds of persisting in the engineering program increased by approximately 0.5; for each 100 points higher on SAT math, the odds of staying in the engineering program increase by 1.4; and for each point higher on the 5-point Likert scale for Conscientiousness, the odds increase by 4.2.

The logistic regression model for final-year persistence includes significant predictors SAT math, Conscientiousness, and creative self-efficacy (Table 5). This model was based on 77 observations of complete cases, and therefore the significance and goodness-of-fit measures are more robust (likelihood ratio $\chi^2 = 20.08$, $p < 0.001$, Nagelkerke $R^2 = 0.318$, $p < 0.001$, Wald tests on each predictor, $p < 0.01$). This model predicting more long-term persistence indicates that the odds of persisting in the engineering program to and through the final undergraduate year increase by 1.6 for each 100 points on SAT math and by 3.40 for each point on the 5-point Likert measure of Conscientiousness, and that students are less likely to persist for each point higher on the 5-point Likert scale for creative self-efficacy. This model correctly predicted student persistence 73% of the time.

We further explored this model by calculating the probability that students with varying levels of creative self-efficacy would persist to graduation, holding SAT math (600.5) and Conscientiousness (3.41) constant at their mean levels (Table 6). Students who viewed themselves

Table 4 Logistic Regression Model Predicting First-Year Retention

Predictor	Odds ratio-estimate	95% CI on odds ratios	p-value
High school rank	1.045	[1.002, 1.098]	0.051^{+}
SAT math	1.014	[1.002, 1.028]	0.037*
Conscientiousness	5.175	[0.983, 39.32]	0.073^{+}

$^{+}p < 0.10$, $^{*}p < 0.05$.

Table 5 Logistic Regression Model Predicting Long-Term Retention

Predictor	Odds ratio-estimate	95% CI on odds ratios	p-value
SAT math	1.016	[1.006, 1.027]	0.003**
Conscientiousness	4.403	[1.555, 15.19]	0.009**
Creative self-efficacy	0.448	[0.227, 0.817]	0.012*

$^{*}p < 0.05$, $^{**}p < 0.01$.

as highly creative (average score of 4 or 5) were only 52% to 71% likely to graduate in engineering compared with students who viewed themselves as moderately creative (85%; average score of 3) and students who viewed themselves as not very creative (92% to 95%; average score of 1 or 2).

Table 6 Effect of Creative Self-Efficacy on Persistence

Creative self-efficacy (5 = high)	Probability of persisting
5	0.52
4	0.71
3	0.85
2	0.92
1	0.95

Does creativity predict academic achievement in engineering? How does the role of creativity in academic achievement change over time? The linear regression model to predict first-year GPA included the statistically significant variables of high school rank, SAT math, and Conscientiousness (Table 7). Agreeableness was also a significant predictor. The model was based on 51 observations of complete cases and explained approximately 45% of the variation in the first-year GPA (adjusted $R^2 = 0.4535$). The goodness of fit of the model was sufficient, on the basis of an F-test against the intercept-only model, $F(4, 46) = 11.37$, $p < 0.001$. The model indicates that first-year GPA (on a 4-point scale) increased by 0.12 for every decile increase in high school rank, one-third of a letter grade for every 100-point increase in SAT math, and one-third of a letter grade for every point increase in Conscientiousness (on a 5-point scale). Although marginal ($p < 0.10$), a point increase in Agreeableness on a 5-point scale resulted in a decrease in first-year GPA by approximately 0.22.

The linear regression model to predict final-year GPA shows similar results (Table 7). The model was based on 35 observations of complete cases, and explained approximately 55% of the variation in the final-year GPA (adjusted $R^2 = 0.5386$). The goodness of fit of the model was sufficient, $F(3, 31) = 14.23$, $p < 0.001$. The model indicates that final-year GPA (on a 4-point scale) increased by 0.11 for every decile increase in high school rank, approximately one-third of a letter grade for every 100-point increase in SAT math, and one-quarter of a letter grade for every point increase in Conscientiousness (on a 5-point scale). Agreeableness was not a significant predictor in this analysis.

Cohort, sex, and first-generation status were included in the full model for backwards regression and were ultimately removed. In addition, each factor was individually included in the forward regression models; none were statistically significant at the $p < 0.10$ level, and none were included in the final model. Assumptions were verified for all four models, including normality of residuals, linearity, and heteroskedasticity. Our measures were valid for the purpose of our study and our sample.

Table 7 Linear Regression Model for GPA

	First-year GPA		Final-year GPA	
Predictor	Point estimate	p-value	Point estimate	p-value
High school rank	0.012	0.002**	0.011	0.004**
SAT math	0.003	0.002**	0.004	<0.001***
Conscientiousness	0.329	0.016*	0.246	0.022*
Agreeableness	−0.227	0.077⁺		

⁺ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Finally, an exploratory principal components analysis was performed on the six creativity measures to uncover possible underlying dimensions of creativity. Results indicated that only one principal component had a standard deviation above the typical cutoff value of 1, but it explained just 25% of the variance. We used the one dominant principal component to form a new generalized creativity variable, but it did not reach the level of significance in any of the regression models. This result, along with the fact that four principal components only explained 75% of the variance, confirmed our decision to retain all six creativity measures as separate variables.

Discussion

Creativity as a Predictor

As expected, SAT math, high school rank, and Conscientiousness were significant predictors of engineering student persistence and achievement (as measured by GPA). Measures of general creativity were not significant predictors of engineering student GPA, but creative self-efficacy was negatively related to engineering student persistence in the major.

These results indicate that creative performance is not strongly encouraged or rewarded in the curriculum, and therefore is not a factor predicting GPAs of undergraduates in engineering. Our results are consistent with recent findings that most engineering education programs do not deliberately teach or reward creativity (Cropley, 2015a; Daly et al., 2014). While our specific curriculum at Elizabethtown College has a project design course in six out of eight semesters, these courses are often 1- and 2-credit courses that may not factor substantially in the GPA calculation compared with the 3- and 4-credit traditional courses that emphasize "right answers" and critical thinking. Despite our research interest in creativity, at this point, like many other traditional ABET-accredited engineering programs, we do not place particular emphasis on creativity or deliberately consider it in our grading. Other researchers have found that engineering instructors are not familiar with teaching or evaluating creativity, even during design projects and open-ended assignments (Cropley, 2015a; Kazerounian & Foley, 2007; Zappe, Mena, & Litzinger, 2013). Recent work by Katz-Buonincontro, Davis, Aghayere, and Rosen (2016) used the experience-sampling method with engineering technology students to elicit student beliefs about creativity in the classroom. Their results indicated that students were frustrated during a first course emphasizing creativity, but had an increased positive experience in a second course. Perhaps most important, the engineering technology students were consistently less willing to express a creative idea when an instructor was present (Katz-Buonincontro et al., in press). This unwillingness to be creative in front of instructors may indicate that engineering instructors do not react positively to creative ideas or that students are worried about having the "right answer" in front of instructors. According to the investment theory (Sternberg & Lubart, 1995), it is no surprise that the classroom environment discouraged creativity.

Interestingly, our results indicate that creative self-efficacy is significantly negatively related to long-term engineering student persistence in the major. According to the logistic regression model, a student with average SAT math and Conscientiousness who views himself as highly creative is only about 50% likely to remain in the engineering major, while a student who views herself as not very creative is about 90% likely to remain in the engineering major. Again, this result is consistent with the idea that engineering students may see engineering as the technical implementation of ideas, rather than closely identifying engineering with the idea-generation phases of design. In interviews with undergraduates in the United States and

Australia, Cropley (2015a) found that students held the view that engineering programs are dominated by “convergent, analytical work and passive knowledge acquisition” and do not reward creativity (p. 163). Early results from a cross-sectional study of approximately 800 undergraduates in 13 engineering disciplines by Zappe, Reeves, Mena, and Litzinger (2015) similarly found that self-reported creative identity scores were statistically lower among a cohort of seniors than a different cohort of first-year students, while creative expectations were significantly much lower for seniors than for first-year students. Zappe et al. (2015) suggested that students do not feel they have further developed creative capacities in the engineering curriculum and that by senior year they no longer believe that creativity is important in the engineering field. They further hypothesized that in light of these results, it may be that highly creative students are no longer in the engineering cohort, and called for a study evaluating creativity and engineering student persistence. Our findings support this hypothesis.

This migration of highly creative students out of the engineering major may also be more pronounced at our small liberal arts institution. Students at our institution are not required to apply directly to the engineering major; rather, any student accepted to the college may enroll in the introductory physics, calculus, and engineering courses. This open enrollment process might result in less commitment to engineering on the part of the enrolled students. Furthermore, it is extremely easy to switch into another major where there are no discipline-specific colleges; therefore, students might switch out of engineering more readily. However, our retention rates are comparable with other institutions, so these effects are likely small. Ultimately, it appears that one measure of how well students view their “fit” with the engineering major is a lack of creativity.

The same negative relationship between creative self-efficacy and persistence that was not seen in the first year may be due to the small sample upon which the first-year persistence model was based. It is possible that first-year students may base decisions to persist in engineering primarily on their academic performance (GPA) rather than on their fit with the major.

Change in Predictors Over Time

From the first to the final year, predictors for engineering student GPA stayed consistent. However, high school rank was a significant predictor of first-year persistence, but was not a factor in predicting final-year persistence. Instead, creative self-efficacy was a significant negative predictor of longer-term persistence into the final year and to graduation. According to our results, if engineering programs are interested in persistence to graduation, it is more valuable to know students’ creative self-efficacy than their high school rank. This finding alone confirms the importance of continuing to study creativity in engineering education.

Our results involving background, academic aptitude, and personality traits are consistent with the literature (Astin & Astin, 1992; Besterfield-Sacre et al., 1997; French et al., 2005; Hall et al., 2015; Kamphorst et al., 2015; Mendez et al., 2008; Veenstra et al., 2008, 2009). SAT math was the most significant predictor of both engineering student persistence and achievement, in both the first and final years. For each 100 points increase in SAT math, the model predicted a third of a letter grade increase in both first-year and final GPA, and that a student had about one and a half times higher odds of persisting in engineering.

As in many studies, high school rank was a significant predictor of engineering student persistence and achievement. Unlike as in other studies, we evaluated outcomes after the first year and in the final year, and we found that high school rank had a weaker influence later in the student’s undergraduate studies. High school rank had a significant relationship and a larger effect on first-year GPA than on final-year GPA, and was significant in predicting early but not later persistence. It is likely that high school rank indicates academic preparation relevant to the first-year courses such as Physics I and II and Calculus I and II. However, in subsequent years the students likely reach an equivalent level of basic preparation and begin taking courses that are completely new material for everyone. In terms of persistence in the major, the academic preparation may help some students avoid leaving the major due to poor performance in the first year, and may affect how students view themselves early in their academic studies (as a serious student or someone who doesn't give up, for example), but the decision after the first year to graduate with an engineering degree is influenced less by high school preparation and previous achievement than by perception of fit with the major.

We also corroborated the results of a recent study by Hall et al. (2015) on personality traits as factors in engineering student persistence, and likewise found that Conscientiousness was a significant predictor of student persistence. While Hall et al. (2015) focused only on persistence, we showed a similar relationship for GPA as well, with a point increase in Conscientiousness score (approximately one standard deviation, on a 5-point scale) related to a third of a letter grade increase in the first-year GPA, and a quarter of a letter grade increase in final-year GPA. Similarly, a point higher Conscientiousness score resulted in about four times higher odds of persisting in the first year, and about three times higher odds of persisting to graduation. Hall et al. (2015) found that for one standard deviation increase in Conscientiousness, the odds of staying in the program more than doubled. Conscientiousness likely expresses itself in practical terms because students who are more aware of deadlines and more careful and thorough with their work generally have strong study habits and high motivation to succeed. Like high school rank, Conscientiousness lessened slightly in both significance and importance over the students' undergraduate careers. It is likely that some students who scored lower on the Conscientiousness scale when entering college developed more conscientious work habits during their time in the engineering program. Also likely is that students with low Conscientiousness scores drop out, and they are no longer in the fourth-year cohort.

We found another personality factor that reduced first-year GPA: Agreeableness. Agreeableness was negatively correlated to first-year GPA (along with Extraversion) and was also a predictor of first-year GPA. It is likely that while both variables showed a negative correlation, only one had enough of a unique contribution to GPA in the regression model to be statistically significant. Other studies of personality traits and achievement in higher education have not found a relationship between Agreeableness and academic achievement. However, these studies posited that students who are more agreeable may be better at cooperative learning tasks, but they may also be more likely to spend time socializing and doing activities with clubs and organizations, which might take time and focus away from academic pursuits (Chamorro-Premuzic & Furnham, 2008; Hall et al., 2015).

Limitations

A limitation of this study is the restriction to one institution and the resulting small sample. Elizabethtown College has a small engineering program housed in a liberal arts setting, and our results may not be generalizable to students in other settings, such as large public universities. Our institution has approximately 1,800 undergraduate students with about 150 students in the engineering program. Eighty-five percent of students live on campus and students are highly involved in clubs and Division III athletics. Our institutional student-to-faculty ratio is 12:1, the average class size is 18 students, and the four-year graduation rate is

71%. Our students are accepted into the engineering program in the first semester by indicating an intended major of engineering, and there are no additional requirements beyond admission to the college. As a result, it is reasonably easy for our students to switch to a major other than engineering without applying to another division or college; this ease of transferring might account for a higher rate of highly creative students readily leaving engineering. Although we are very interested in creativity as a research topic, our engineering curriculum does not place particular emphasis on creativity. Despite these aspects of a small college and small sample, our results are similar to those Nazzal's (2015) study on creativity and problem solving in engineering students. With a sample size of 505 students at a medium-sized public university in the northeast United States, Nazzal found that overall creativity did not predict overall GPA or engineering GPA, and that creativity was similarly not associated with sex, personality characteristics, or creative self-efficacy. Due to the inherently small number of students in small liberal arts programs similar to ours, the literature is lacking in studies that test if well-established conclusions at large research universities hold true at small programs where the engineering student experience is quite different. Our work confirming that engineering student persistence and achievement are related to a strong math background and high school achievement adds to that small body of literature and expands the literature on creativity in engineering students.

In addition, the small number of students in our program necessitated the combination of cohorts and resulted in the inability to draw conclusions about potential differences in sex and ethnicity. To moderate this limitation, we tested for differences in every variable between cohorts, sexes, and first-generation status, and included each of these variables individually in the regression model, but all variables lacked statistical significance. However, we realize we may not have a large enough sample to detect these differences, and so we deliberately refrain from drawing conclusions about the absence of differences in effects among different sexes and ethnic minorities. Studies with much larger samples have found that sex, ethnicity, and citizenship do affect graduation from engineering programs (Zhang, Anderson, Ohland, & Thorndyke, 2004). Effects of sex and ethnicity on creativity and creative performance are an active and ongoing area of research (e.g., Kaufman, Niu, Sexton, & Cole, 2010).

Our study focused on general creativity rather than a discipline-specific measure of creativity in the context of engineering or design. While it is important to first establish the relationship between general creativity and engineering student persistence and achievement, many studies suggest that general creativity may be distinct from discipline-specific creativity (Baer, 2012; Baer & Kaufman, 2005). The investment theory also predicts a positive relationship between domain knowledge and creativity (Sternberg & Lubart, 1995). The knowledge and abilities that allow a person to make a creative contribution are not the same across domains. Some domains require a high level of novelty (e.g., arts), whereas others place more value on relevance and effectiveness of innovative ideas (e.g., engineering; Csikszentmihalyi, 1996). Several of our creativity measures, such as the dream project essay, are focused more on writing than on spatial thought. Ongoing work in our research lab is evaluating the effects on persistence and achievement of engineering creative self-efficacy, prior achievements in science and math, and more spatial design-oriented tasks that are rated by expert engineers with 10 years of post-baccalaureate experience.

Despite these limitations, our results are consistent with the literature on factors predicting student persistence and achievement, and corroborate results from a recent study on personality traits.

Conclusions and Implications for Practice

Conclusions

Our results show that in addition to the well-established factors of SAT math, high school rank, and Conscientiousness, knowledge of a student's level of creative self-efficacy improves the ability to predict persistence to the final year and graduation. However, the fitted model indicates that students who view themselves as highly creative are less likely to remain in engineering to graduation. Among a group of self-described highly creative students with average SAT math and Conscientiousness scores, only half of them will persist in an engineering program. In comparison, over 90% of those who view themselves as not very creative will persist.

While creative self-efficacy is negatively related to engineering student persistence, none of the creativity measures predicted GPA in either the first year or in final years; the lack of influence on GPA suggests that some engineering curricula may not deliberately encourage or reward creativity at the level of course grades. Creative self-efficacy and the creativity measures do not exhibit the same relationship to the outcomes; these results add to the growing body of literature suggesting that creative self-efficacy does not always reflect creative performance (Pretz & McCollum, 2014; Reiter-Palmon, Robinson-Morral, Kaufman, & Santo, 2012).

Furthermore, factors predicting engineering student persistence and achievement change throughout the students' undergraduate studies in engineering: high school rank and Conscientiousness become less important over time. It is likely that students' academic preparation entering college becomes less important as all students establish the same baseline knowledge and attempt more advanced material that none of them have previously been exposed to. It is also likely that students with low entering levels of Conscientiousness cultivate study habits associated with this trait as they mature in the engineering program, or that students with low Conscientiousness scores have departed.

Implications

The implications for engineering education practitioners are significant. First, if students with weaker high school backgrounds are academically supported during their first year in college, the effects of high school preparation lessen over time. Understanding this phenomenon may help programs admit and support students from a wider variety of high school backgrounds. Intentionally developing habits consistent with Conscientiousness during a first-year seminar, introduction to engineering course, or academic advising may help students quickly improve GPAs and stay in the engineering major.

The result that creativity is not a factor in predicting engineering student GPA adds quantitative evidence to the recent body of literature suggesting that creativity is not appropriately taught or rewarded in some engineering curricula. Cropley (2015a) and Zappe et al. (2013) have identified obstacles to deep integration of creativity in engineering education; these range from the lack of a consistent definition of creativity and the discomfort of engineering instructors with teaching and assessing creativity, to more systematic issues including the disciplinary focus on narrow specialization and factual, technical knowledge. Both also noted the lack of published studies focusing on creativity (excluding innovation, entrepreneurship, and problem solving) in the engineering education literature. Zappe et al. (2013) noted that from 2006 to 2011, only 16 articles in the five top journals in engineering education focused on creativity or the creative process. Ten of these were in the *International Journal of Engineering*

Education, and most of the articles were not empirical studies of creativity, but were instead reports on classroom activities meant to enhance student creativity.

Finally, the indication that engineering students may not view creativity as an element of fit in the engineering major or field is cause for concern and should be explored further. As suggested in the *Changing the Conversation* report (National Academy of Engineering, 2008), deliberately marketing creativity as important to an engineering career may encourage creative individuals to enroll in an engineering program, but then the emphasis on creativity must be continued throughout the student experience in engineering curricula (Cropley, 2015a). All engineering educators can learn about creativity and enhance creativity in the classroom and in grading. Brent and Felder (2014) recently published some practical tips for encouraging both creative and critical thinking in an active learning environment. At a higher level, engineering educators and administrators can incorporate creativity as a consideration in curriculum development. Cropley (2015a) has recently laid out a number of principles and strategies to guide curriculum design around incorporating creativity. Engineering education researchers and journal editors can support rigorous empirical studies and cross-disciplinary collaborations with educational psychologists. Ultimately, until engineering students see creativity rewarded in their grades and emphasized in their curriculum, the engineering field will miss the opportunity to retain and develop more creative engineers.

Appendix A
Variables Considered in the Analysis

	Type	*n*	Description
Demographic			
Cohort	Factor	85	Students entering in 2011 ($n = 45$) or 2012 ($n = 40$)
Sex	Factor	85	Male (n = 72) or female ($n = 13$)
First generation	Factor	80	First-generation student, yes ($n = 40$) or no ($n = 40$)
High school size	Number	61	High school size; range of 38 to 756
Academic aptitude			
SAT math	Number	77	SAT score for math; range of 200 to 800
SAT critical reading	Number	77	SAT score for critical reading; range of 200 to 800
SAT writing	Number	77	SAT score for writing; range of 200 to 800
High school rank	Number	55	High school rank; range of 1 to 99 percentile
Personality measures (Big Five)			
Extraversion	Number	85	Average score; range of 1 to 5
Agreeableness	Number	85	Average score; range of 1 to 5
Conscientiousness	Number	85	Average score; range of 1 to 5
Neuroticism	Number	85	Average score; range of 1 to 5
Openness	Number	85	Average score; range of 1 to 5
Creativity measures			
Creative self-efficacy	Number	85	Average score; range of 1 to 5
Creative achievement	Number	85	Log of CAQ; range of 0 to 1.6
Caption creativity	Number	85	Captioning picture; average score; range of 1 to 6
Essay creativity	Number	85	Essay on dream project; average score; range of 1 to 6
Divergent thinking	Number	83	Two divergent thinking tasks; average rating across activities; range of 1 to 6

Appendix (continued)

	Type	*n*	Description
Persistence outcome measure			
Retained first year	Factor	85	Retained after first-year; present ($n = 64$) or not present in major ($n = 21$)
Retained	Factor	85	Retained if engineering major in final year; present ($n = 56$) or not present ($n = 29$)
Achievement outcome measure			
First-year GPA	Number	77	GPA end of first year; range of 0 to 4
Final-year GPA	Number	55	GPA beginning of end of final year, depending on cohort (only for students still in engineering program; range of 0 to 4)

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