The Relation of Personality, Gender, and Self-Efficacy to Achievement in College Science Classes

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Abstract

This study explores mediational relationships between gender, self-efficacy, personality, and class achievement in university physics classes for a sample of 1576 students. The neuroticism facet significantly mediated the effect of gender on self-efficacy. Self-efficacy mediated the relationship between the conscientiousness facet and class achievement. While neuroticism had no significant effect on regression models for men with or without the mediation of self-efficacy, self-efficacy strengthened the relationship between neuroticism and achievement for women.

Introduction

A substantial body of research has demonstrated that personality as measured by the Big Five Inventory (BFI, Goldberg, 1992; John et al., 1991; 2008) has a significant relation to academic performance (Poropat, 2009); however, less research has investigated the role of personality at the college level, particularly in Science, Technology, Engineering and Mathematics (STEM) classes. These classes often suffer from a substantial underrepresentation of women (de Cohen & Deterding, 2009) and are of particular interest because of the projected shortfall of STEM graduates in the US (Olson & Riordan, 2012). Personality differences between men and women measured by the BFI are well documented (Srivastava et al., 2003) opening the possibility that part of the underrepresentation of women in STEM classes is related to personality and its effect on other variables affecting academic performance or retention.

Self-efficacy was defined by Bandura (1994, p. 71) as "people's beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives." Self-efficacy has been shown to be strongly correlated with academic achievement (Britner, 2008; Multon, Brown, & Lent, 1991; Richardson, Abraham, & Bond, 2012) and is important in models of retention and persistence (Larson et al., 2014; Lent, Brown, & Larkin, 1986, 1987; Sawtelle, Brewe, & Kramer, 2012). Many studies have reported differences in self-efficacy between men and women (Authors, 2019; Betz & Hackett, 1981; Huang, 2013); these differences may partially explain the underrepresentation of women in STEM (Cheryan, Ziegler, Montoya, & Jiang, 2017).

Both personality, primarily the conscientiousness facet, and self-efficacy are strongly related to academic achievement. In a 2012 meta-analysis, Richardson et al. showed that the correlation between conscientiousness and academic achievement was $r = .19$ and the correlation be academic self-efficacy and academic achievement was $r = .31$. Other personality facets were more weakly correlated with achievement. These correlations were larger than those with other well-studied non-cognitive variables such as locus of control and goal orientation.

Bandura's Social Cognitive Theory (SCT) (1977) is a recursive theory where self-efficacy affects performance decisions which then affect performance outcomes. The success or failure of these outcomes affects future self-efficacy. Personality should affect the development of self-efficacy by modifying performance decisions and thus performance outcomes. As such, any effect of personality on achievement may act though an effect on self-efficacy.

Many studies have investigated the relationship between personality facets and self-efficacy: conscientiousness (Chen, Casper, & Cortina, 2001), openness (Sánchez-Cardona et al., 2012), agreeableness (Caprara et al., 2010), extraversion (Judge & Ilies, 2002), and neuroticism (Schmitt, 2008). Chen et al. (2001) showed conscientiousness mediated the effect of self-efficacy on performance. Other studies have investigated the change in the relationship between the personality traits and academic performance when self-efficacy is introduced to the models (Caprara et al., 2011). Conscientiousness has been shown to act indirectly on achievement by influencing academic self-beliefs (Caprara et al., 2011). Self-efficacy also mediated the effect of past academic performance on present academic performance (Diseth, 2011). Little work has examined how these effects differ for men and women.

This study seeks to address two research questions. *[RQ1] Does personality mediate the relation of gender and self-efficacy? [RQ2] Does self-efficacy mediate the effect of personality on academic achievement? If so, how does the mediation differ for men and women?*

Methods

This study was conducted in the introductory calculus-based physics classes at an eastern land-grant institution in the US serving approximately 30,000 students. These classes are taken by physical science and engineering majors (74% men, 26% women). Data were collected from the fall 2015 to fall 2018 semester.

The student's personality was measured using the Big Five Inventory (BFI, Goldberg, 1992; John et al., 1991; 2008). The BFI measures the 5-factor personality model with facets: extraversion, agreeableness, conscientiousness, neuroticism, and openness. Self-efficacy toward the physics class was measured using the "Self-Efficacy for Learning and Performance" subscale from the Motivated Strategies for Learning Questionnaire (MSLQ, Pintrich et al., 1993). This instrument is widely used (Duncan & McKeachie, 2005) and is well validated (Pintrich et al., 1993). Both surveys were administered once per semester; students received a small amount of course credit for completing each survey. Informed consent was collected from all participants; the Institutional Review Board approved all procedures.

Academic achievement was operationalized as physics test averages collected from course instructors and converted to a percentile scale. Gender was dichotomously coded with women as zero and men as one.

A total of 3177 students completed the physics classes from fall 2015 to spring 2018. Of these, only domestic students with ACT or SAT scores were retained leaving 2419 participants. Of these, 1576 students completed both surveys; these students form the sample for this study.

Mediation is investigated within the framework developed by Baron and Kenny (1986) to explore the relation of an Independent variable (Indep), a Dependent variable (Dep), and a Mediator (Med). Figure 1 presents a path model for the relation of these variables. The total effect, c, is measured through the regression: $Dep = i_1 + c \cdot Indep + e_1$ where i_1 represents the intercept and e_1 the remaining error. With the mediator, Dep acts through two paths: the Direct Path characterized by c' and the Indirect Path through the mediator composed of a path from Indep to Med (a) and the path from Med to Dep (b). These parameters are measured by the regression equations: $Med = i_2 + a \cdot Indep + e_2$ and $Dep = i_3 + b \cdot Med + c' \cdot Indep + e_3$. The mediation is significant if a, b, and c are significant regression coefficients and if $c' < c$. To further demonstrate significant mediation, bootstrapping with 1000 replications was used to show the 95% confidence interval of the total indirect effect ($a \cdot b$) does not include zero.

Results

Table 1 presents the descriptive statistics for the five personality facets, self-efficacy, and achievement in college physics classes measured by test average. A substantial difference ($d = .75$) in the neuroticism facet was measured between men and women, with women having higher values of the facet. This is consistent with previous studies (Authors, 2016; Srivastava et al., 2003). Women are also measured with higher Agreeableness and Conscientiousness, both small effects. Men have higher self-efficacy toward the class, a small effect. This is consistent with other work showing men with generally higher self-efficacy in engineering and physical science classes (Authors, 2019; Usher & Pajares, 2008). This difference is counter to the actual difference in achievement with women earning similar test averages (women also earn significantly higher course grades, a small effect, and have equal ACT scores showing the populations come to the class with similar academic preparation). Table 2 presents the correlation matrix with men above the diagonal and women below.

[RQ1] Does personality mediate the relation of gender and self-efficacy? The strong differences between men and women on conscientiousness and neuroticism, along with the strong correlation of these facets as well as openness and self-efficacy led us to focus this study on these three facets. Models with agreeableness and extraversion were constructed and no significant mediation effects were found. Figure 2 shows the overall model explored in this study; paths that were not significant are not shown. The figure suggests multiple possible mediational effects; these were tested independently.

The mediation of the personality facets on the relation between gender and self-efficacy was tested (Indep = Gender, Dep = Self-Efficacy, and Mediator = (Conscientiousness, Neuroticism, or Openness). The results are shown in Table 3. Only the neuroticism facet showed both a substantial reduction of the total effect and a total indirect effect whose 95% confidence interval did not include zero. Nearly half the effect of gender on self-efficacy can be explained by the difference in neuroticism between men and women. This result is particularly important because the difference in self-efficacy between men and women in the face of equal or superior class performance by women has been a substantial mystery.

[RQ2] Does self-efficacy mediate the effect of personality on academic achievement? If so, how does the mediation differ for men and women? The second set of mediational relationships suggested by Figure 2 involve the mediation by self-efficacy of the relation between personality and physics class performance measured by test average (Indep = (Conscientiousness, Neuroticism, or Openness), Mediator = Self-Efficacy, Dep = Test Average). This analysis disaggregates men and women; the substantial difference in neuroticism raises the possibility that this facet might inadvertently become a surrogate for other gender effects in an aggregated regression. The results of this mediation analysis are shown in Table 4. The part of the indirect path from both neuroticism and conscientiousness to self-efficacy (a) was significant for both men and women; the magnitude of the regression coefficients were also similar for men and women and consistent with what would be predicted theoretically. Conscientious, completing required assignments, should increase class success and improve self-efficacy; neuroticism, a tendency to experience anxiety, should decrease test performance, and lower self-efficacy. Mathematics and science anxiety are well-established effects and lower test performance equally for men and women (Else-Quest, 2010; Ma, 1999; Mallow 2010). Self-efficacy significantly mediated the effect of conscientiousness on test average for both men and women to the extent that the direct path (c') was no longer significant. The total effect (c) of openness on test average was not significant for either men or women, so no mediational relationship could exist; however, openness had the strongest direct relation (a) with self-efficacy in the combined model (Figure 2). As such, openness does affect test average but only through its effect on self-efficacy. Neither the total effect (c') nor the direct path (b) was significant for the neuroticism facet for men. For women, the total effect of neuroticism on test average (c') was significant; this effect was strengthened when self-efficacy was added as a mediator.

An aggregated analysis was also performed and is shown in Figure 2. Various interaction effects were explored; only the interaction between gender and neuroticism was significant. This had the effect of making the combined model consistent with the disaggregated models lowering the effect of neuroticism on test average for men.

Discussion/Conclusion

This work showed that the neuroticism facet mediated differences in self-efficacy and explained 45% of the total difference in self-efficacy by gender. This serves to partially explain the substantial literature reporting self-efficacy differences in physical science, engineering, and mathematics disciplines (Authors, 2019; Betz & Hackett, 1981; Huang, 2013). The effect of conscientiousness on test average was mediated by self-efficacy approximately equally for men and women. This result is consistent with SCT where more conscientious students should have superior class outcomes throughout school; these should lead to increased self-efficacy. Neuroticism negatively influenced self-efficacy for men but had no additional effect on test average. For women, the action of the neuroticism facet was not as would be predicted. A significant but small positive total effect of neuroticism on test average was measured; this effect was increased when self-efficacy was added as a mediator. A substantial literature suggests higher susceptibility to stress should lower exam performance and as a result lower self-efficacy (Else-Quest, 2010; Ma, 1999; Mallow 2010). While substantial additional research is needed to

understand the effect, it is possible that higher levels of neuroticism for women cause lower levels of self-efficacy than is commensurate with ability. The positive relation of neuroticism to test average serves to correct for lower levels of self-efficacy in women than are consistent with achievement by predicting high test averages for women with higher neuroticism than would normally be predicted based on self-efficacy.

Tables and Figures

Table 1

Descriptive Statistics

	Total M ± SD	Men M ± SD	Women M ± SD	Cohen's d
Test Average	70 ± 15	70 ± 15	71 ± 14	.02
SEPC	3.8 ± .8	3.9 ± .8	3.7 ± .8	.29***
Agreeableness	3.8 ± .5	3.8 ± .5	3.9 ± .6	.25***
Conscientiousness	3.6 ± .6	3.7 ± .5	3.9 ± .6	.31***
Extraversion	3.2 ± .7	3.2 ± .7	3.3 ± .8	.06
Neuroticism	2.8 ± .7	2.7 ± .6	3.2 ± .7	.75***
Openness	3.7 ± .5	3.7 ± .5	3.7 ± .5	.04

Note: Personality and self-efficacy facets are measured on a 5-point Likert scale. Test average is reported as a percentile. The mean M and standard deviation SD are reported. Effect size is measured with Cohen's d (.2 = small effect, .5 = medium effect, and .8 = large effect). The significance of the difference between men and women is reported along with d. * denotes $p < .05$, ** $p < .01$, and *** $p < .001$.

Table 2

Correlation Matrix

		1	2	3	4	5	6	7
1.	Test Average	-	.49***	-.02	.13***	-.08**	-.04	.05
2.	Self-Efficacy	.50***	-	.09**	.22***	.05	-.18***	.20***
3.	Agreeableness	-.05	.06	-	.33***	.08**	-.20***	.12***
4.	Conscientiousness	.17***	.20***	.28***	-	.17	-.30***	.07*
5.	Extraversion	-.17***	.08	.19***	.17***	-	-.20***	.16***
6.	Neuroticism	.11**	-.18***	-.33***	-.18***	-.19***	-	-.08
7.	Openness	.07	.14**	.15**	.10	.15**	-.02	-

Note: Results for men are presented above the diagonal; women below the diagonal. * denotes $p < .05$, ** $p < .01$, and *** $p < .001$.

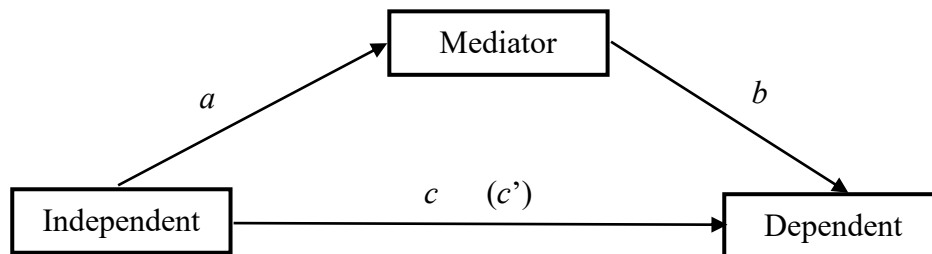Figure 1

General Mediation Path Model

Figure 2

Full Model – Paths without significant regression coefficients were removed.
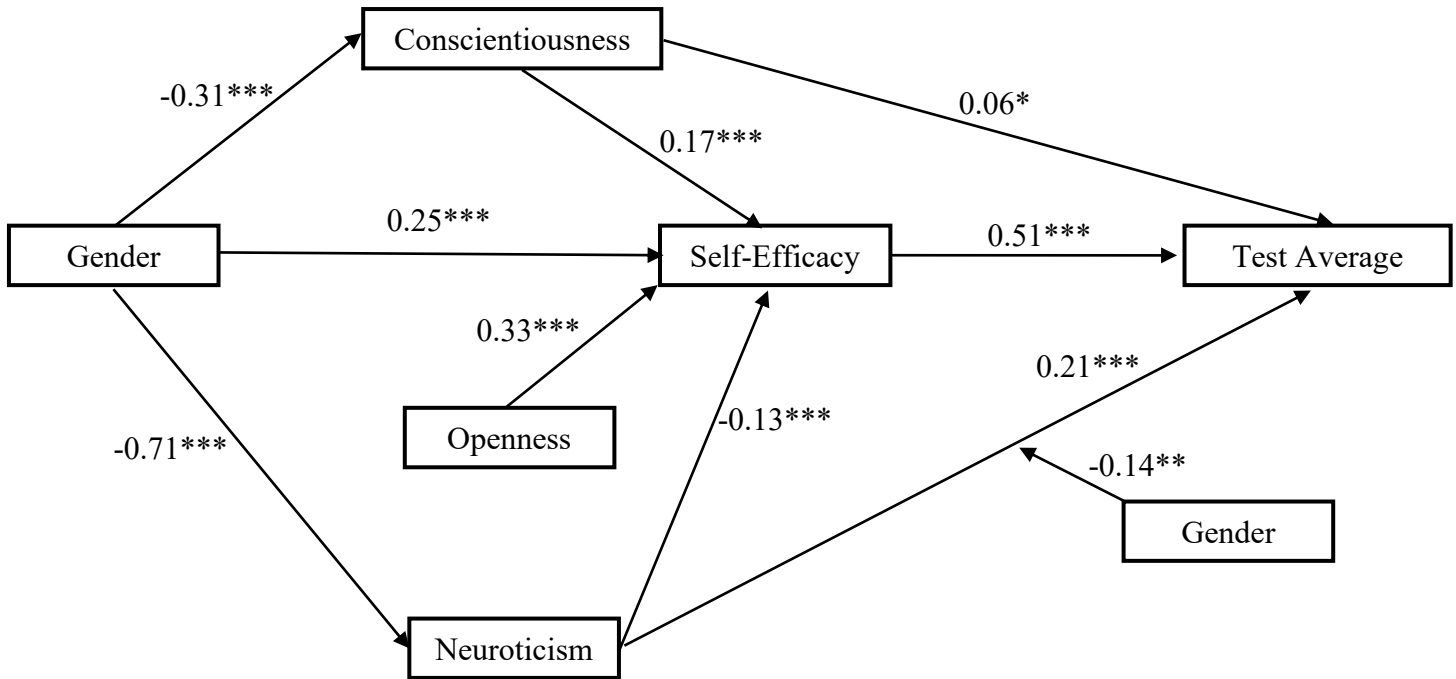
Table 3

Mediation of Personality Facets on the Effect of Gender on Self-Efficacy

| | Mediator | | | | | |
| | Conscientiousness | | Neuroticism | | Openness | |
	B	SE	B	SE	B	SE
Direct Path						
Gender → Self-Efficacy (c')	.35***	.06	.16**	.06	.29***	.06
Indirect Path						
Gender → Mediator (a)	-.31***	.06	-.71***	.05	-.02	.03
Mediator → Self-Efficacy (b)	.22***	.02	-.18***	.03	.37***	.05
Total Effect (c = c' + a · b)	.29***	.06	.29***	.06	.29***	.06
Total Indirect Effect (a · b)	-.06 [-.10, -.04]		.13 [.09, .17]		-.01 [-.03, .01]	
% of Effect through Mediator	16%		45%		3%	

Note: The regression coefficient B and its standard error SE are reported. For the total indirect effect, the value in brackets is the 95% confidence interval determined by bootstrapping. * denotes $p < .05$, ** $p < .01$, and *** $p < .001$.

Table 4

Mediation by Self-Efficacy on the effect of the Personality Facets on Achievement (Test Average)

| | Independent (Indep) Variable | | | | | |
| | Conscientiousness | | Neuroticism | | Openness | |
	B	SE	B	SE	B	SE
Men						
Direct Path						
Indep → Test Average (*c'*)	.02	.03	.05	.03	-.09	.05
Indirect Path						
Indep → Self-Efficacy (*a*)	.22***	.03	-.18***	.03	.42***	.06
Self-Efficacy→ Test Average (*b*)	.49***	.03	.50***	.03	.50***	.03
Total Effect (*c = c' + a · b*)	.13***	.03	-.04	.03	.11	.06
Total Indirect Effect (*a · b*)	.11 [.08, .14]		-.09 [-.12, -.06]		.21 [.14, .27]	
% of Effect through Mediator	84%		66%		69%	
Women						
Direct Path						
Indep → Test Average (*c'*)	.07	.04	.21***	.04	-.01	.08
Indirect Path						
Indep → Self-Efficacy (*a*)	.20***	.05	-.17***	.05	.27**	.09
Self-Efficacy→ Test Average (*b*)	.49***	.04	.54***	.04	.50***	.04
Total Effect (*c = c' + a · b*)	.17***	.05	.11*	.05	.12	.09
Total Indirect Effect (*a · b*)	.10 [.05, .15]		-.10 [-.15, -.04]		.13 [.04, .23]	
% of Effect through Mediator	60%		32%		93%	

Note: The regression coefficient B and its standard error SE are reported. For the total indirect effect, the value in brackets is the 95% confidence interval determined by bootstrapping. * denotes $p < .05$, ** $p < .01$, and *** $p < .001$.

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