

## **Self-Efficacy, Mathematical Mindset, and Self-Direction in First-Year Engineering Students**

**Dr. Matthew Cavalli, Western Michigan University**

Dr. Cavalli is Professor of Mechanical and Aerospace Engineering and Associate Dean in the College of Engineering and Applied Sciences. His technical research interests include materials behavior and solid mechanics. His educational interests include distance education and first-year student success. He has previously served as the Chair of the Materials Division of ASEE.

**Ms. Anetra Grice, Western Michigan University**

Anetra Grice is has served as the STEP Program Director for Western Michigan University's College of Engineering and Applied Sciences for since 2010.

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## **Introduction**

Incoming first-year students in engineering, engineering technology, and computer science at Western Michigan University (WMU) are placed into cohorts according to their preferred major and initial math placement level. Cohort members share at least two courses (usually three or four) during each of their first two semesters with the goal of encouraging study group formation and peer support. Peer tutoring and faculty/staff mentoring are also provided. The format, which was established with a grant from the National Science Foundation and had been in place since 2004, has led to significant gains in both retention and graduation rates in the College of Engineering and Applied Sciences (CEAS). CEAS is working to identify additional support programs to complement the gains that have already been made. Part of this work involves trying to establish traits shared by successful (and non-successful) students.

For the past two fall semesters, first-year students in CEAS have been recruited to complete a start-of-semester survey that includes questions related to aspects of their personality as well as self-efficacy and mindset. Various previous research has linked specific personality traits to academic success of students (e.g., [1-6]). Based on a review of the literature, personality questions were drawn from components of the Big Five personality inventory [7], which is one of the most well-regarded instruments for this purpose. An advantage of the Big Five inventory compared to assessments like the Meyers-Briggs Type Indicator [8], is that the Big Five inventory places individuals on a continuum of personality traits rather than in distinct categories. Personality components included in the Big Five inventory include Extraversion, Agreeableness, Openness to Experience, Conscientiousness, and Neuroticism. Of these, those that have been most commonly linked to student success (particularly for engineering students) are Openness to Experience and Conscientiousness.

Researchers have also investigated the connections between students' mindset and their academic success (e.g., [9-12]). Results have been mixed. For example, a meta-analysis of studies related to students' mindset failed to show universal benefit [11]. However, the same analysis highlighted the potential of impact of mindset for students who were less prepared for their program of study than their peers [11,12]. In addition to mindset, previous research has shown that a student's level of self-direction can be related to academic success [6,13,14].

This prior work led to the inclusion of questions related to Conscientiousness, Openness, Mindset, and Self-Direction (in addition to self-efficacy) in the survey administered to first-year students in CEAS at the start of the Fall 2019 semester [15]. Surprisingly, very few personality aspects were found to have a statistically significant correlations with either students' first semester GPA or their retention to the second semester. Positive self-direction and a student's level of confidence that they would graduate from WMU had the most universal impacts. Based on these results, the survey for students entering in Fall 2020 was modified to remove questions related to Openness, modify the questions related to general mindset to focus on mathematical (rather than general) intelligence, and to add questions related to educational attainment by the

student's parents and other family members. Results from Fall 2019 were also reanalyzed to include information about retention to Fall 2020 (the students' third regular semester).

### **Experimental Methods/Materials/Project Approach**

Due to the ongoing pandemic and associated restrictions, respondents for the Fall 2020 survey were recruited virtually; the survey was also administered online. All first-time in any college (FTIAC) students in the College of Engineering and Applied Sciences were invited to participate via email. Students were invited to participate in both a start-of semester survey and end-of semester survey, but only start-of-semester results are reported here. Participant consent was gathered as the first page of the online survey before moving on to the main questions. Students who completed the survey were entered into a drawing for one of three \$50 gift cards. Three hundred fifty-seven eligible students were initially invited to participate in the study; eleven students requested a total withdrawal from their classes and these were removed from the analysis, leaving a potential pool of three hundred forty-six students. Ninety-two FTIAC students responded to the initial survey – a participation rate of 26.6%. Tables 1 and 2 show the demographics of the FTIAC participants as well as the overall demographics of the Fall 2020 CEAS FTIAC group, respectively. Female students were significantly overrepresented in the respondent group but the racial distribution was reflective of the overall population.

**Table 1: Demographics of Fall 2020 start-of-semester survey FTIAC respondents**

Male	Female	White	Non-white
61 (66.3%)	31 (33.7%)	68 (73.9%)	21 (22.7%)

**Table 2: Demographics of all Fall 2020 CEAS FTIACs**

Male	Female	White	Non-white
273 (78.9%)	73 (21.1%)	260 (75.1%)	78 (22.5%)

The Fall 2020 survey incorporated 20 questions related to Conscientiousness (10 positive and 10 negative) drawn from the open-source question bank of the Oregon Research Institute [16]. Ten mindset-related questions were also included. The questions were adapted from [17,18] to focus on mathematical intelligence rather than intelligence in general. The questions were modified because results from a similar survey of CEAS FTIAC students in Fall 2019 [15] showed few statistical correlations between responses to the general mindset questions and first semester GPA or second semester enrollment. Questions related to self-direction [14] and confidence in eventually graduating from either college in general or WMU in particular were also included. Students responded to these questions using a Likert scale from 1-5 (does not describe me at all to describes me very well or not at all confident to extremely confident, respectively). Three additional questions related to the highest level of education attained by the student's parents as well as any family members with engineering degrees were included as well as a question about the most recent math class completed in high school.

Students' survey responses were compiled with information about gender, race, high school GPA, Fall 2020 living arrangement (on-campus or off-campus), first semester math course grade, overall first semester GPA, and enrollment status for the Spring 2021 semester. Statistical correlations were investigated between first semester GPA and second semester enrollment

(proxies for ‘student success’) and each of the other factors using one-way ANOVA. For each aspect of personality (positive conscientiousness, negative conscientiousness, self-direction, positive mathematical mindset, negative mathematical mindset), responses to all relevant items were averaged, resulting in a single overall score that was used for statistical evaluation. Second semester enrollment was classified as continuing in CEAS, continuing at WMU, or non-enrolled. No distinction was made between full-time or part-time enrollment for the second semester. Unless otherwise specified below, ‘enrollment’ should be understood to mean second semester enrollment in CEAS. Results reported as being ‘statistically significant’ were at the 95% confidence level unless otherwise stated.

## Results and Discussion

Tables 3 and 4 summarize the statistically significant correlations that were identified between student success (first semester overall GPA or second semester enrollment) and various demographic factors or factors from the student survey. Correlations at levels below 95% confidence are identified. Details of the correlations are presented in the relevant section of text.

**Table 3: Summary of correlations identified with first semester GPA for F20 cohorts and sub-cohorts – details presented in text. Confidence levels lower than 95% indicated.**

	All FTIACs	Surveyed FTIACs	Male	Female	White	URM	Algebra II	Pre-Calculus+
H.S. GPA	X	X	X	X (90%)	X (90%)			X
Math GPA	X	X		X	X	X		X
Neg Consc		X		X		X	X (90%)	

**Table 4: Summary of correlations identified with second semester enrollment in CEAS for F20 cohorts and sub-cohorts – details presented in text. Confidence levels lower than 95% indicated.**

	All FTIACs	Surveyed FTIACs	Male	Female	White	URM	Algebra II	Pre-Calculus+
Math GPA	X	X	X	X	X	X (90%)		X
Campus Res	X							
Neg Consc		X		X		X		
Pos Math Mindset		X (90%)		X (90%)				X (85%)
Conf Grad Coll		X	X		X (90%)	X (90%)		X
Conf Grad XXX		X	X			X (85%)		X
Last HS Math					X			

### *Cohort – All F20 FTIACs*

Evaluation of all Fall 2020 (F20) FTIAC students (including those who participated in the survey and those who did not) showed a statistically higher first semester university GPA for students whose high school GPA was above 3.5 compared to those students with a high school GPA below this level. High school GPA was not statistically significant for second semester enrollment for this cohort, however. First semester university math GPA was positively correlated to overall first semester GPA. Students with a first semester math GPA over 1.0 were statistically more likely be retained to the second semester than students who did not. Living on campus was not statistically significant with regards to first semester GPA, but students who

lived on campus were more likely to be retained to the second semester than students who did not.

#### *Cohort – F20 FTIACs Completing the Start-of-Semester Online Survey*

Both high school GPA and first semester math GPA were positively correlated to first semester overall GPA for FTIAC students who completed the survey. As with the overall FTIAC cohort, survey completers with a high school GPA of at least 3.5 had higher first semester GPAs than those who did not. Survey completers with a first semester math GPA between 1.0 and 3.0 achieved statistically similar overall first semester GPAs, while those of students with math grades higher than 3.0 achieved higher overall GPAs and students who failed their first math course (< 1.0 math GPA) achieved lower overall GPAs. With regards to second semester enrollment for this cohort, math course GPA was not statistically significant, but withdrawing from the first math course had a significant negative effect.

Two personality aspects were found to have statistical significance for this cohort – negative conscientiousness and mathematical mindset. Survey completers reporting a negative mathematical mindset less than 3 out of 5 were statistically more likely to have a higher overall GPA and to enroll in CEAS in the Spring 2021 semester. Students who reported a positive mathematical mindset at the level of 3 or 5 were statistically more likely to enroll in the second semester than students reporting a level less than 3 (although the confidence level was 90%). Students who reported that their confidence in graduating from college and graduating from WMU was at least 3 out of 5 were statistically more likely to enroll for the second semester compared to students reporting a lower level of confidence.

#### Sub-cohorts: F20 Male vs. Female Survey Responders

When analyzed by gender, both men and women with high school GPAs over 3.5 were statistically likely to have a higher first semester overall GPA compared to students who didn't. However, the confidence level for women was only 90% compared to 95% for men. Negative conscientiousness was inversely correlated to both first semester overall GPA and second semester enrollment for women but not for men. Women with a negative conscientiousness score of less than 3 out of 5 were statistically likely to have a higher overall GPA and to enroll for a second semester compared to women who did not. In contrast, men who reported a higher level of confidence in graduating (both overall and from WMU) were statically more likely to enroll for a second semester. This effect was not present for women. Women who reported a positive mathematical mindset greater than 2 out of 5 were statistically more likely to enroll for a second semester but the confidence level of the correlation was 90%. No correlation between mathematical mindset on the GPA or second-semester enrollment of men was identified.

#### Sub-cohorts: F20 White vs. Non-white/Underrepresented Minority (URM) Survey Responders

Both high school GPA and first semester math GPA showed positive correlations with overall first semester GPA for white survey completers. For URM survey completers, first semester math GPA was positively correlated with first semester GPA; high school GPA was not. Negative conscientiousness was inversely correlated with first semester GPA for URM

respondents, with scores lower than 3 correlating to higher overall GPAs than scores of 3 or more. With regards to second semester enrollment, negative conscientiousness also showed an inverse correlation for URM students but not for white students. Confidence in graduation from college showed a positive correlation for both sub-cohorts but only at the 90% confidence level. For white students, having taken a math class in high school higher than Algebra II correlated to a higher probability of second semester enrollment, the only time this factor was found to correlate with student success for any cohort or sub-cohort.

#### Sub-cohorts: F20 Pre-Calculus or higher vs. Algebra II Survey Responders

No factors correlated to first semester GPA for students enrolled in Algebra II during their first semester at the 95% confidence level. Negative conscientiousness responses less than 3 is correlated to higher first semester GPAs for these students at the 90% confidence level. For students enrolled in Pre-Calculus or higher, both high school GPA over 3.5 and first semester math GPA over 3.0 had positive correlations with first semester GPA. For second semester enrollment, no factors were found to have statistical significance for students enrolled in Algebra II. Students enrolled in Pre-Calculus or higher showed positive correlations between second semester enrollment and confidence in graduation scores higher than 2 out of 5. A weak positive correlation (85% confidence level) was found between positive mathematical mindset and second semester enrollment for this cohort.

#### *Cohort – F19 FTIAC Survey Responders*

Fall 2020 enrollment was investigated for students who responded to a similar survey in Fall 2019. Each of the personality trait survey questions as well as high school GPA, mathematical GPA, etc. were evaluated for statistical correlation with Fall 2020 enrollment. Interestingly, despite positive mindset not being statistically significant for either first semester GPA or second semester enrollment for most Fall 2019 cohorts or sub-cohorts, positive mindset was almost universally correlated to Fall 2020 (third semester) enrollment. Students who reported a positive mindset of 4 or 5 out of 5 were statistically more likely to have enrolled in CEAS for Fall 2020 compared to students with a positive mindset level below 4. The two sub-cohorts for which the positive statistical correlation between positive mindset and enrollment was not found were underrepresented minority students and students who were enrolled in Algebra II during the Fall 2019 semester. The correlation for women was slightly weaker, at the 90% confidence level. For both URM students and women, confidence in having chosen a correct major was negatively correlated to enrollment in the third semester. Students with the highest confidence (5 out of 5) were less likely to have enrolled in Fall 2020 compared to students with lower scores.

### **Conclusions**

It should be noted that the unique context of this study within the COVID-19 pandemic renders interpretation of these results to ‘normal’ years (even back to 2019) problematic, at best. With that caveat, several items of note were identified. First, despite positive self-direction being positively correlated to second semester enrollment for several cohorts and sub-cohorts from the Fall 2019 semester, no such relationship was found for the Fall 2020 CEAS FTIAC survey responders. This is somewhat surprising given the move to more online learning for Fall 2020,

requiring students to, in some cases, balance multiple course delivery platforms and work submission mechanisms. A reasonable hypothesis is that students scoring higher on a scale of positive self-direction would be more likely to thrive in such an environment, but this was not supported by data. This does not necessarily mean that self-direction was entirely unrelated to student success for Fall 2020 FTIAC students. Only positive self-direction questions were included on this year's survey. Both positive and negative questions were included in Fall 2019, but only the positive questions were found to be correlated to student success. Both positive and negative conscientiousness questions were included but only negative questions were found to have correlations to aspects of success for some cohorts. It is possible a similar trend would have been observed with the negative self-direction questions.

The second interesting outcome stems from the correlation of positive mindset to third semester enrollment for most cohorts and sub-cohorts of Fall 2019 FTIAC survey completers. This was extremely surprising given the limited correlations of either positive or negative mindset scores with first semester GPA or second semester enrollment. It is possible that the correlation with third semester enrollment is due, at least in part, to the unique conditions of the pandemic. It will be interesting to see if a similar result is observed for Fall 2020 FTIACs with the modified mathematical mindset questions (in, hopefully, a largely post-pandemic environment).

Third, for all cohorts and sub-cohorts, not withdrawing from the first semester math class was positively correlated to second semester enrollment at or above the 90% confidence level. The only exception was students enrolled in Algebra II during their first semester. For some groups, there were additional positive correlations based on grade in the first math course (all FTIACs, female survey responders). No similar correlations between first semester math GPA and student success were identified for Fall 2019 students [15].

Fourth, the survey responses most often correlated with success for Fall 2020 FTIACs were negative conscientiousness (for first semester GPA) and confidence in graduating (for second semester enrollment). Low scores on negative conscientiousness questions correlated with higher first semester GPAs, but high positive conscientiousness scores did not show a similar relationship. Graduation confidence was positively correlated to student success (both first semester GPA and second semester enrollment) for Fall 2019 FTIACs, the only survey responses found to be significant for both years of students. The relationship between students' commitment to graduation and academic success has been noted in various retention models in the literature [19,20].

Finally, while increasing high school GPA was positively correlated with increasing first semester overall GPA across most cohorts and sub-cohorts, no correlations were identified between high school GPA and retention to the second semester for Fall 2020 students. This is consistent with results from Fall 2019 students. The result is somewhat surprising given previous research in the literature showing positive correlations between prior achievement and future academic success [21] but may be due in part to the significant changes in expectations and responsibilities as students transition from high school to college. Some students who experienced success in high school may find that their toolkit of study strategies and academic approaches is insufficient for the demands of university coursework.

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