Using Measures of Academic Tilt and Measured Interest Tilt to Predict Math-Intensive STEM Degree Completion

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This study examined the value of using measures of academic "tilt" and vocational interest "tilt" to predict the likelihood that students majoring in a STEM-related field will complete a math-intensive STEM degree in a timely manner. Academic tilt looks at students' relative academic strengths by appropriately comparing their math and science achievement levels to their English, reading, and social studies achievement levels. Vocational interest tilt measures are based on students' People/Things and Data/Ideas work-task dimension scores that underlie the ACT World-of-Work map. Results suggested that having a relative strength in math and science achievement and having a tilt toward Things on the People/Things dimension are positively related to completing a math-intensive STEM degree within four years of initial enrollment, after statistically controlling for ACT Composite score, high school coursework taken and grades earned, major intentions, certainty of major intentions, and gender.

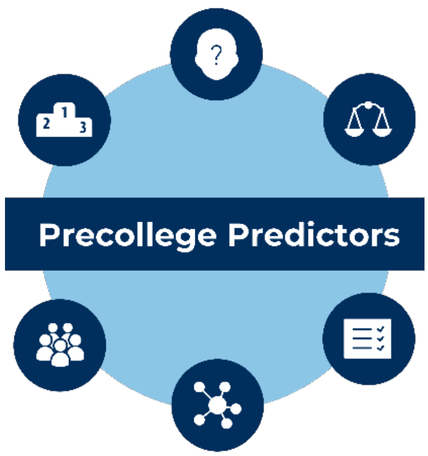
A recent study by Westrick, Radunzel, and Bassiri (2018) found that having a relative strength in math and science achievement versus English, reading, and social studies achievement was positively related to declaring a math-intensive STEM major in college.

Additionally, the researchers found that having a tilt toward things and ideas on Prediger's (1982) People/Things and Data/Idea work-task dimensions for measured vocational interests was associated with an increased likelihood of a student declaring a STEM major.[1] The findings on the relative academic strengths and tilt measures held even after statistically controlling for other student characteristics that have been identified as being related to STEM major choice as well as to the likelihood of persisting and succeeding in a STEM major (Radunzel, Mattern, & Westrick, 2016, 2017). These additional predictors included mathematics and science academic achievement levels, high school coursework taken and grades earned, major intentions, certainty of major intentions, and gender. The Westrick et al. (2018) study also found that female students were less likely than male students to declare a math-intensive STEM major.

As a follow-up to the Westrick et al. (2018) study, the current study explores whether students' relative academic strengths and vocational interest tilt measures are related to the likelihood of completing a math-intensive STEM degree in a timely manner among STEM majors and whether their effects on degree completion differ by gender. More specifically, the first objective examines whether having STEM-related tilt in terms of achievement and vocational interests is predictive of completing a bachelor's degree in a math-intensive STEM field within four years, after statistically controlling for academic achievement, high school coursework taken and grades earned, major intentions, certainty of major intentions, and gender. In light of other research that suggests that differences in relative academic strengths and interests may contribute to the gender gaps in math-intensive STEM fields (Coyle, Purcell, Snyder, & Richmond, 2014; Davison, Jew, & Davenport, 2014; Lubinski & Benbow, 2007), the second objective of this study was to evaluate whether the relationships between STEM degree completion and the academic achievement and tilt measures depended upon gender.

Data and Methods

The study sample was comprised of nearly 48,000 students who had taken the ACT® in high school, enrolled as first-time entering postsecondary students in fall 2005 through fall 2009, declared a STEM major within two years of initially enrolling in college, had at least four years of follow-up data, and completed the ACT registration questionnaire items examined in this study. These students were from 47 four-year institutions. To be included, an institution was required to have a minimum of 30 students in STEM majors. The sample has been described in an earlier ACT study by Radunzel et al. (2016) that examined the role of academic preparation and interest on STEM success.[2]



Precollege predictors included ACT Composite score, high school grade point average (HSGPA), ACT tilt (difference in standardized mean ACT math and science scores minus standardized mean ACT English and reading scores), HSGPA tilt (difference in standardized high school math and science GPA minus standardized high school English and social studies GPA), and People/Things and Data/Ideas tilt measures. The People/Things and Data/Ideas tilt measures were derived from students' ACT Interest Inventory scores and represent the coordinates on the People/Things and Data/Ideas dimensions that underlie the ACT World-of-Work map and connect measured interests to career clusters (see Westrick et al., 2018, for a more complete discussion on these variables). Variables on a continuous scale were standardized and converted to z-scores using the means and standard deviations from a national reference group of ACT-tested students from fall 2003 through spring 2009.[3] Categorical predictors included intended academic major (categorized as math-intensive STEM, other STEM [medical and health], and undecided), certainty of major intentions (categorized as very sure, fairly sure, not sure), taking high school Calculus (yes = 1, no = 0), taking high school Physics (yes = 1, no = 0), and gender (female = 0, male = 1).

Hierarchical logistic regression models with random slopes and random intercepts were used to estimate students' chances of earning a bachelor's degree within four years in one of the following math-intensive STEM fields: Engineering and Technology, Computer Science and Mathematics, and Natural Sciences.[4] The first model (labeled Model 1) incorporated the following achievement measures and student background variables: ACT Composite scores, HSGPA, gender, intended major, sureness of intended major, the interaction between intended major and sureness of intended major, taking Calculus in high school, and taking Physics in high school. Results from Model 1 were used for comparative purposes. The second model (labeled Model 2) included all the variables from the first model (Model 1) plus the four standardized tilt measures: ACT tilt, HSGPA tilt, People/Things tilt, and Data/Ideas tilt. Model 2 was used to answer the first objective. The third model (labeled Model 3) included all the variables from the second model (Model 2) and added the interactions between gender and the standardized academic achievement and tilt measures: ACT Composite score, HSGPA, ACT tilt, HSGPA tilt, People/Things tilt, and Data/Ideas tilt. Model 3 was used to answer the second objective.

To assess model fit, the typical accuracy rate (AR) and logistic *R* across institutions was calculated. The AR is the estimated proportion of students correctly identified as completing or not completing a math-intensive STEM degree within four years. The logistic *R* is the standard deviation of the estimated logit function (Allen & Le, 2008), and it measures the overall predictive strength of the model. The greater the logistic *R* is, the stronger the relationship is between the predictors and the criterion. This measure is derived in a manner analogous to that for the multiple *R* in multiple linear regression, but it is appropriate for logistic regression models. Given that it is the standard deviation of the estimated logit function, it is not bounded between 0 and 1 as is the multiple *R*.

Results

Overall, 19% of the sample completed a bachelor's degree in a math-intensive STEM field within four years; however, this rate varied across institutions (median=14%, 25th percentile=7%, and 75th percentile=20%). Additionally, completion of a math-intensive STEM degree was found to be related to student characteristics. This is illustrated in Tables 1, 2, and 3 that provide the results of the analyses for completing a math-intensive STEM degree completion within four years for Models 1, 2, and 3, respectively.

In the first model (Table 1), HSGPA and ACT Composite score were found to both be positively related to completing a math-intensive STEM degree within four years. For example, the odds of completing a STEM degree in a timely manner was 2.14 times greater for every one standardized unit increase in the ACT Composite score. Other statistically significant predictors included intending to major in a math-intensive STEM field (adjusted OR = 1.44), taking a Calculus course (adjusted OR = 1.31), and taking a Physics course (adjusted OR = 1.08) in high school.[5] After statistically controlling for the other variables in the model, there was not a statistically significant difference in the four-year math-intensive STEM degree completion rate between male and female students. The median logistic *R* was 1.245 across institutions and the median AR was .867.

Table 1. Predicting Math-Intensive STEM Degree Completion within Four Years, Model 1

Variable	Estimate	SE	*t* Value	*p* Value
Intercept	**-3.192**	**0.137**	**-23.35**	**<.001**
Intended Major				
Math-Intensive STEM Major	**0.366**	**0.098**	**3.73**	**<.001**
Medical & Health STEM Major	-0.002	0.122	-0.02	.986
Undecided	0.137	0.088	1.54	.129
Sureness of Intended Major*				
Very Sure	-0.031	0.094	-0.33	.744
Fairly Sure	0.074	0.083	0.89	.376
Intended Major x Major Sureness Interaction				
Math-Intensive STEM x Very Sure	-0.010	0.112	-0.09	.931
Medical & Health STEM x Very Sure	-0.048	0.137	-0.35	.729
Math-Intensive STEM x Fairly Sure	-0.015	0.101	-0.15	.885
Medical & Health STEM x Fairly Sure	-0.054	0.124	-0.43	.667
ACT Composite Score	**0.760**	**0.043**	**17.48**	**<.001**
HSGPA	**0.954**	**0.038**	**25.18**	**<.001**
High School Calculus	**0.267**	**0.046**	**5.80**	**<.001**
High School Physics	**0.077**	**0.029**	**2.65**	**.011**
Gender	0.094	0.058	1.63	.111
Model Fit	N	Median	Min	Max
Logistic R	47	1.245	0.586	1.563
Accuracy Rate	47	.867	.627	.978

*Major sureness was examined for students with an intended major only; it was not evaluated for undecided students. An additional indicator for whether the student had an intended major (coded as 1) compared to undecided students (coded as 0) was multiplied by the major sureness main effect and intended major/major sureness interaction terms to ensure the inclusion of the undecided students in the sample used to estimate the math-intensive STEM degree completion models. Significant predictors ($p < .05$) are **bolded**. SE = standard error.

Table 2 provides the results for Model 2. The predictors identified from Model 1 as being significantly related to completing a math-intensive STEM degree remained significantly related in Model 2 with the exception of taking Physics in high school. Two of the tilt measures – ACT tilt and People/Things tilt – were found to be significantly related to completing a math-intensive STEM degree in a timely manner. Both tilt measures were positively related, meaning that students whose standardized mean ACT math and science score exceeded their standardized mean ACT English and reading score (adjusted OR = 1.25), and students who had greater measured interest in working with Things rather than with People (adjusted OR = 1.08) were more likely to complete a bachelor's degree in a math-intensive STEM field.[6] The non-significant gender effect again suggested no difference in completing a math-intensive STEM degree between males and females after statistically controlling for the other variables in the model. HSGPA and ACT

Composite score remained the strongest predictors in Model 2. Compared to Model 1, the model fit was slightly better, with an increase in the median logistic *R* of 0.028 but only a slight increase in the median AR of .001.

Table 2. Predicting Math-Intensive STEM Degree Completion within Four Years, Model 2

Variable	Estimate	SE	*t* Value	*p* Value
Intercept	**-3.133**	**0.136**	**-23.07**	**<.001**
Intended Major				
Math-Intensive STEM Major	**0.293**	**0.102**	**2.88**	**.006**
Medical & Health STEM Major	-0.059	0.127	-0.47	.642
Undecided	0.097	0.089	1.09	.282
Sureness of Intended Major*				
Very Sure	-0.002	0.098	-0.02	.988
Fairly Sure	0.088	0.087	1.01	.316
Intended Major x Major Sureness Interaction				
Math-Intensive STEM x Very Sure	-0.039	0.117	-0.34	.737
Medical & Health STEM x Very Sure	-0.041	0.144	-0.29	.775
Math-Intensive STEM x Fairly Sure	-0.042	0.106	-0.40	.692
Medical & Health STEM x Fairly Sure	-0.027	0.130	-0.21	.834
ACT Composite Score	**0.770**	**0.045**	**17.17**	**<.001**
HSGPA	**0.949**	**0.036**	**26.25**	**<.001**
High School Calculus	**0.229**	**0.047**	**4.90**	**<.001**
High School Physics	0.055	0.030	1.82	.075
Gender	-0.017	0.059	-0.28	.781
ACT-Tilt	**0.225**	**0.025**	**9.16**	**<.001**
HSGPA-Tilt	0.078	0.042	1.87	.067
People/Things Tilt	**0.077**	**0.022**	**3.44**	**.001**
Data/Ideas Tilt	-0.019	0.018	-1.07	.291
Model Fit	N	Median	Min	Max
Logistic R	47	1.273	0.619	1.559
Accuracy Rate	47	.868	.631	.979

*Major sureness was examined for students with an intended major only; it was not evaluated for undecided students. An additional indicator for whether the student had an intended major (coded as 1) compared to undecided students (coded as 0) was multiplied by the major sureness main effect and intended major/major sureness interaction terms to ensure the inclusion of the undecided students in the sample used to estimate the math-intensive STEM degree completion models. Significant predictors (p<.05) are **bolded**. SE = standard error.

Table 3 provides the results addressing the second objective of the study regarding whether the effects of the academic achievement and tilt measures on completing a math-intensive STEM degree differ by gender. A significant interaction effect with gender on STEM degree completion was found for two out of the six predictors – namely, ACT Composite score and ACT tilt. The interaction effects with gender were negative for both predictors, meaning that these predictors were more strongly related to STEM degree completion among female students than among male students. For example, the adjusted OR of completing a math-intensive STEM degree in four years that is associated with a one standardized unit increase in ACT Composite score was estimated to be 2.33 for female students as compared to 2.03 for male students. For ACT tilt, the adjusted OR was 1.34 for female students and 1.18 for male students. As for model fit, the median logistic *R* was 1.280 and the median AR was .870, each up only slightly from Model 2.

Table 3. Predicting Math-Intensive STEM Degree Completion within Four Years, Model 3

Variable	Estimate	SE	*t* Value	*p* Value
Intercept	**-3.142**	**0.140**	**-22.50**	**<.001**
Intended Major				
Math-Intensive STEM Major	**0.288**	**0.102**	**2.83**	**.007**
Medical & Health STEM Major	-0.056	0.127	-0.44	.663
Undecided	0.095	0.090	1.06	.295
Sureness of Intended Major*				
Very Sure	0.003	0.098	0.03	.978
Fairly Sure	0.088	0.087	1.01	.319
Intended Major x Major Sureness Interaction				
Math-Intensive STEM x Very Sure	-0.043	0.117	-0.37	.713
Medical & Health STEM x Very Sure	-0.044	0.144	-0.30	.762
Math-Intensive STEM x Fairly Sure	-0.040	0.106	-0.38	.705
Medical & Health STEM x Fairly Sure	-0.026	0.131	-0.20	.846
ACT Composite Score	**0.844**	**0.049**	**17.33**	**<.001**
HSGPA	**0.886**	**0.054**	**16.30**	**<.001**
High School Calculus	**0.227**	**0.046**	**4.91**	**<.001**
High School Physics	0.055	0.030	1.81	.076
Gender	0.046	0.082	0.56	.577
ACT-Tilt	**0.294**	**0.034**	**8.53**	**<.001**
HSGPA-Tilt	**0.125**	**0.059**	**2.14**	**.038**
People/Things Tilt	**0.063**	**0.027**	**2.36**	**.023**
Data/Ideas Tilt	**-0.045**	**0.020**	**-2.22**	**.032**
Gender x ACT Composite Score	**-0.138**	**0.038**	**-3.62**	**.001**
Gender x HSGPA	0.104	0.067	1.55	.129
Gender x ACT-Tilt	**-0.127**	**0.046**	**-2.74**	**.009**
Gender x HSGPA-Tilt	-0.072	0.070	-1.03	.307
Gender x People/Things Tilt	0.027	0.032	0.84	.404
Gender x Data/Ideas Tilt	0.061	0.035	1.76	.086
Model Fit	N	Median	Min	Max
Logistic R	47	1.280	0.623	1.566
Accuracy Rate	47	.870	.632	.979

*Major sureness was examined for students with an intended major only; it was not evaluated for undecided students. An additional indicator for whether the student had an intended major (coded as 1) compared to undecided students (coded as 0) was multiplied by the major sureness main effect and intended major/major sureness interaction terms to ensure the inclusion of the undecided students in the sample used to estimate the math-intensive STEM degree completion models. Significant predictors (p <.05) are **bolded**. SE = standard error.

Conclusions and Implications

In summary, this study has a number of practical implications for policymakers, educators, and school counselors. First, among the pre-college predictors examined in this study, HSGPA and ACT Composite score were each positively related to completing a math-intensive STEM degree within four years among STEM majors. In addition, students who took Calculus in high school were more likely than those who did not to complete a math-intensive STEM degree in a timely manner. These findings underscore the importance of encouraging students who plan to seek degrees in math-intensive STEM fields to take higher-level mathematics and science courses (including Calculus) to develop strong mathematics and science skills while they are in high school. But, in order to be sufficiently prepared to succeed in these higher-level courses, students need to be learning and developing the necessary foundational skills in these subject areas in earlier grades (ACT, 2008; Bassiri, 2014; Dougherty, 2014).

Second, the current study found that having positive academic tilt (higher on average ACT mathematics and science scores than on average ACT English and reading scores) and having a tilt in vocational interests toward working with Things over People helped to identify students who were more likely to complete a math-intensive STEM degree in a timely manner. The finding on academic tilt provides support for investment and expectancy-value theories that suggest that students' perceived relative strengths on their math and verbal skills can influence students' decisions on how they invest their time and effort (e.g., Wang & Degol, 2013), including college major choice (e.g., Nix, Perez-Felkner, & Thomas, 2015; Porter & Umbach, 2006). The finding on People/Things tilt is in alignment with the placement of math-intensive STEM career areas (e.g., Engineering & Technologies, Natural Sciences & Technologies, and Computer/Info Specialties) on the ACT World-of-Work map (see Figure 1 from Westrick et al., 2018). Both findings highlight the importance of providing students with educational and career guidance early and often. The goal of educational and career guidance programs should be to encourage students to (1) explore career and college options that are a good match with their individual strengths, interests, and values, and (2) acquire the skills and information that is needed to successfully navigate their educational and career goals (Bobek & Zhao, 2015). Encouraging students to explore their interests early and often may help them to align their coursework plans and academic behaviors with their educational degree aspirations as well as future college and career demands and expectations.

Third, the current study did not find a gender difference in four-year math-intensive STEM degree completion rates. However, stronger predictor-outcome relationships with ACT Composite score and the ACT tilt measure were found among female students than among male students. Additionally, even though the interaction term between gender and Data/Ideas tilt was not statistically significant at the 0.05 level (p = 0.086) in Model 3, it is interesting to note that the parameter for Data/Ideas tilt was estimated to be negative (−0.045, p=0.035) and significantly different from zero for female students, but it was estimated to be positive (0.016, p=0.589) for male students, though not significantly different from zero. Future research should explore these relationships in more detail. Such information may help to shed more light on why female students tend to be underrepresented in math-intensive STEM majors.

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Notes

1. Occupations can be organized according to their involvement with these four basic work tasks: working with data (facts, records, numbers, etc.), ideas (abstractions, theories, etc.), people, and things (machines, materials, etc.). Usually one or two of these basic work tasks get at the primary nature of the occupation. The Data/Ideas and People/Things work-task dimensions underlie the ACT World-of-Work map. For more details on these work-task dimensions, see technical documentation on the ACT Interest Inventory and the World-of-Work map (ACT, 2009).
2. The study by Radunzel et al. (2016) imputed missing data for some of the student-level predictors; this was not the case for the current study.
3. See Table 1 from Westrick et al. (2018) for the means and standard deviations for the national reference group.
4. See Table A1 from Radunzel et al. (2016) for a list of the individual Classification of Instructional Program (CIP) codes denoted as STEM.
5. The odds ratio for a predictor is calculated as the exponentiation of the corresponding parameter estimate. For a categorical variable, the OR represents the ratio of the odds of completing a math-intensive STEM degree for a certain subgroup of students (e.g., those taking Calculus in high school) to the odds of completing a math-intensive STEM degree for another subgroup of students (e.g., those not taking Calculus in high school). The odds is the ratio of the probability of experiencing the outcome to the probability of not experiencing the outcome.
6. For a continuous predictor, the OR is interpreted as the increase in the odds of completing a math-intensive STEM degree that is associated with a one-unit increase in the predictor variable.

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