Understanding Mathematics Performance from Student Attitudes and Behaviors: A (Proposed) Multiple-Group Analysis Using International Student Assessment Data

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Policy Issue

Despite empirical evidence on the importance of mathematics proficiency, recent large-scale international assessments (PISA, TIMSS) demonstrate that students from many nations are not performing at expected levels in mathematics (Naemi et. al, in press; Felischman, Hopstock, Pelczar, & Shelley, 2011; Gonzales et al., 2004; Miller, Sen, & Malley, 2007). To date, there have been limited efforts to using the attitude-behavior relationship in understanding achievement outcomes in mathematics as measured through international achievement performance standards.

Theoretical Framework

The theory of planned behavior is based on the assumption that individuals' behavior is determined by their intention to perform a certain behavior. Ajzen proposed three independent determinants of behavior that exert their effects through intention. These determinants are: (1) attitudes (the overall positive or negative evaluation toward an item), (2) subjective norm (the social pressures on the individual to perform a behavior), and (3) perceived behavioral control (the extent to which an individual perceives his/her ability to control the outcome of a behavior).

In the proposed research program we plan to close this chasm and answer a series of questions that relate mathematics attitudes to students' behavior and academic performance. By using the theory of planned behavior (TPB) framework, student attitudes, intentions, and behaviors will be used to predict mathematics performance. A multiple-group analysis is proposed and data from the United States sample is reported.

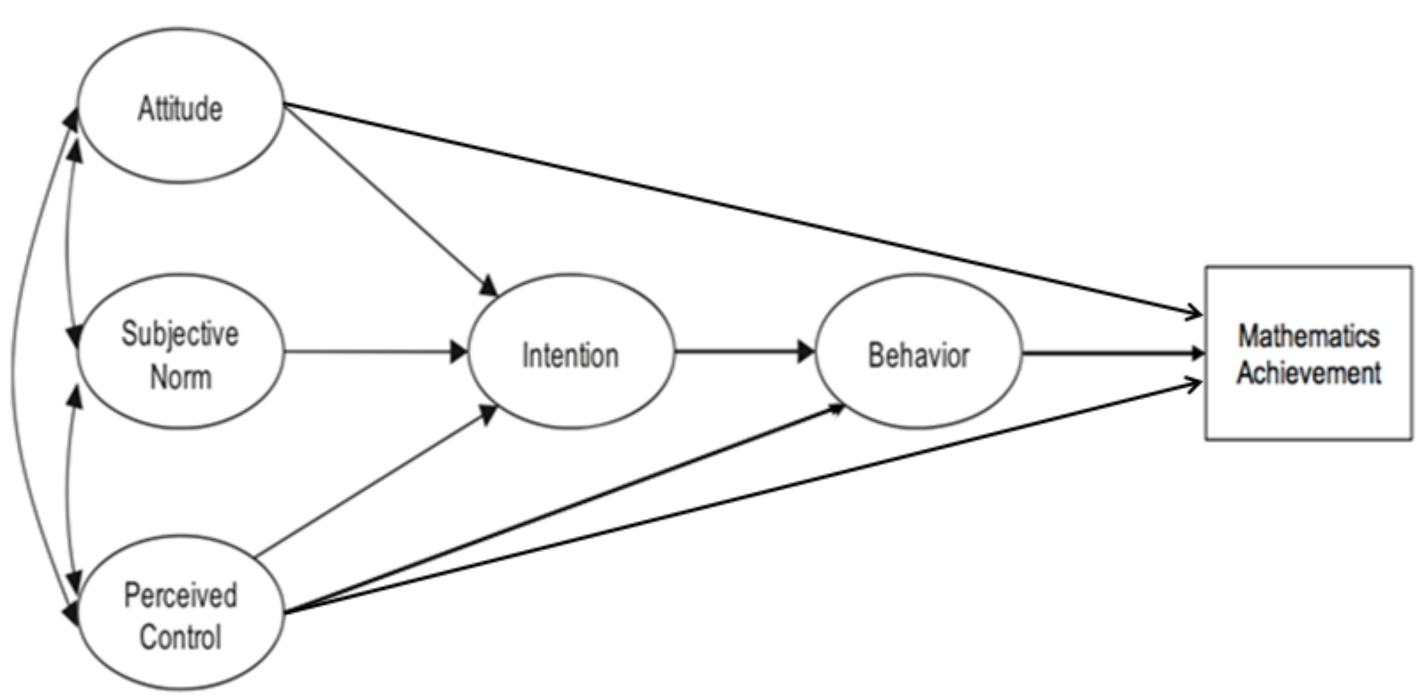


Figure 1. Proposed model for analysis. The theory of planned behavior components and student behaviors predicting mathematics achievement. Adapted from Lipnevich, MacCann, Krumm, Burrus, and Roberts (2011) with the extension of mathematics achievement as an outcome variable.

Research Questions

1. Do the factors of the TPB framework (attitudes, subjective norms, perceived control, intentions, and behavior; see Figure 1) fit the United States PISA data?
2. Does the TPB framework (attitudes, subjective norms, and perceived behavioral control; see Figure 1) explain variance in math-related behavior and performance as included in the PISA data?

Data Source and Analytic Strategy

The United States PISA 2012 data was used (N = 4, 978), which uses complex sampling in order to make generalizations from the data to the population.

The weight command was used (Weight = W_FSTUWT). The replicate weights summarize information about a complex sampling design. In conjunction, the "repweights" command was used (REPWEIGHT=W_FSTR1 - W_FSTR80), which composed 80 Fay's resampling methods used to create the replicate weights (REPSE=Fay).

Stratification and cluster commands are not used when replicate weights are used because the sampling design is already accounted for. Weights are important in complex data in order for the correct standard errors to be computed. Bootstrapping was not used due to the use of replicate weights.

Measurement Model Results

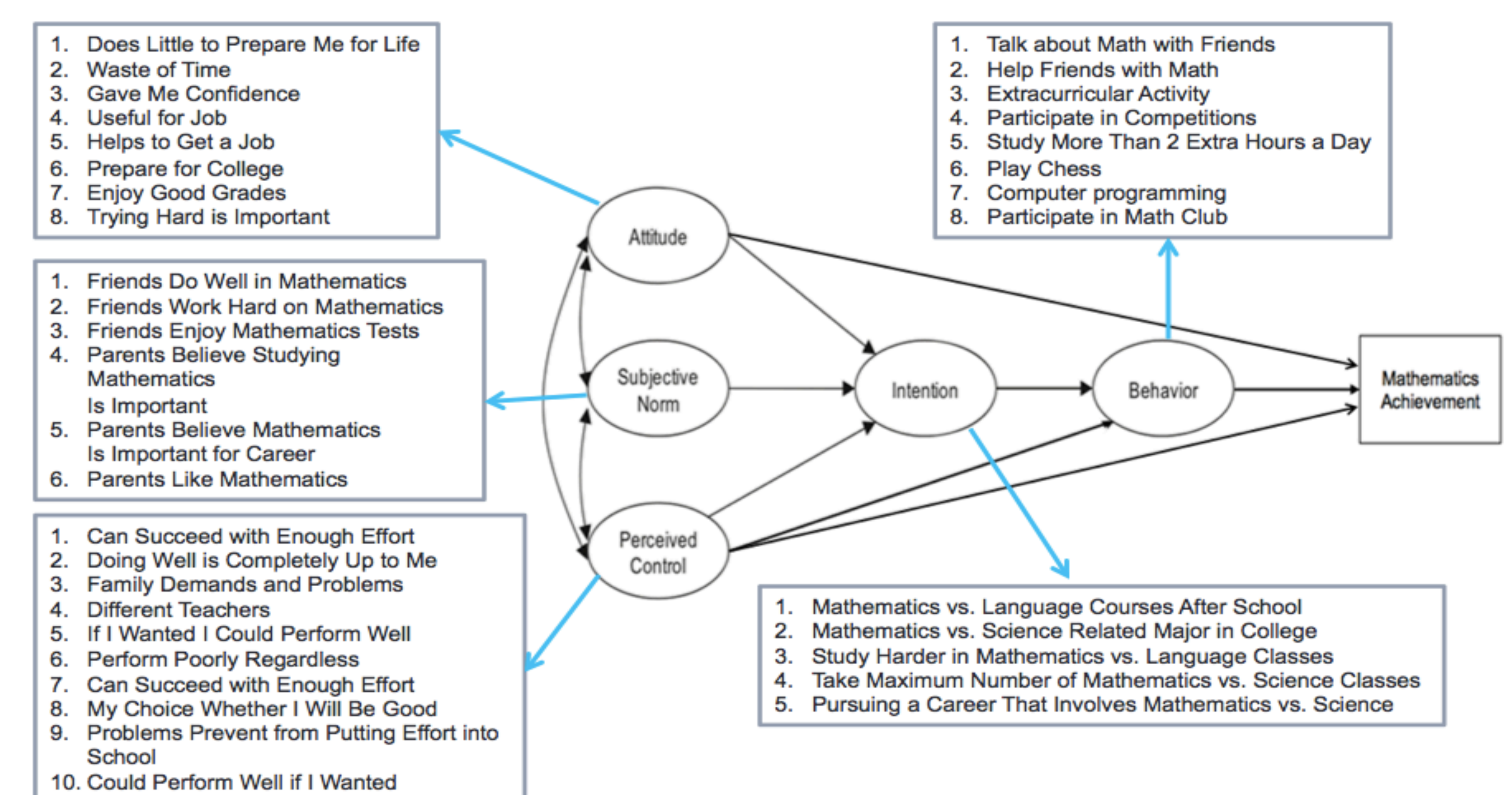
Attitudes, Subjective Norms, and Perceived Control

	Estimate	S.E.	Est./S.E.
ATTITUDE BY			
Does Little to Prepare Me for Life	-0.238	0.015	-16.275
Helps to Get a Job	0.468	0.007	65.565
Prepare for College	0.436	0.008	54.404
Trying Hard is Important	0.448	0.008	55.799
SUBJNORM BY			
Friends Do Well in Mathematics	0.146	0.010	14.999
Parents Believe Study Math Is Important	0.489	0.007	65.193
Parents Believe Math Is Imp. for Career	0.594	0.010	57.548
Parents Like Math	0.388	0.011	36.357
CONTROL BY			
Can Succeed with Enough Effort	0.475	0.010	49.121
Doing Well is Completely Up to Me	0.476	0.010	48.583
Family Demands and Problems	-0.147	0.016	-9.443
If I Wanted I Could Perform Well	0.493	0.011	46.121
Perform Poorly Regardless	-0.349	0.016	-21.586

Intentions and Behavior

	Estimate	S.E.	Est./S.E.
INTENTION BY			
Math vs. Lang Courses After School	0.967	0.005	191.200
Math vs. Science Major in College	0.392	0.018	21.469
Take Max Math vs. Science Classes	0.867	0.008	102.017
Career in Math vs. Science	0.974	0.004	218.584
BEHAVIOR BY			
Talk about Math with Friends	0.706	0.013	38.070
Help Friends with Math	0.719	0.013	33.451
Extracurricular Activity	0.906	0.009	22.728
Participate in Competitions	0.872	0.012	17.934

Note. Model fit statistics for attitude, subjective norms, and control factors indicated good model fit; RMSEA = 0.046, 90 % CI [0.043, 0.049], SRMR = 0.05. Model estimator for intentions and behavior used WRMR (Weighted Root Mean Square Residual) = 7.99. Chi-squared test for model fit not available with replicate weights. All factor loadings were significant; $p < 0.01$.



Note. Math achievement is measured by first plausible value in mathematics performance

Structural Model Results

Total, Total Indirect, Specific Indirect, Direct Effects, And Confidence Intervals

	Estimate	S.E.	Est./S.E.	95% CI
Effects from CONTROL to BEHAVIOR				
Total	0.375	0.021	17.646	(0.334, 0.417)
Total indirect	0.052	0.008	6.535	(0.036, 0.067)
Specific indirect				
BEHAVIOR				
INTENTION				
CONTROL	0.052	0.008	6.535	(0.036, 0.067)
Direct				
BEHAVIOR				
CONTROL	0.324	0.022	14.636	(0.280, 0.367)
Effects from ATTITUDE to MATH				
Total	0.075	0.030	2.559	(0.018, 0.133)
Total indirect	-0.008	0.002	-3.529	(-0.012, -0.003)
Specific indirect				
MATH				
BEHAVIOR				
INTENTION				
ATTITUDE	-0.008	0.002	-3.529	(-0.012, -0.003)
Direct				
MATH				
ATTITUDE	0.083	0.030	2.773	(0.024, 0.142)

	Estimate	S.E.	Est./S.E.	95% CI
Effects from CONTROL to MATH				
Total	-0.365	0.032	-11.452	(-0.427, -0.303)
Total indirect	0.046	0.008	5.772	(0.030, 0.062)
Specific indirect				
MATH				
BEHAVIOR				
CONTROL	0.040	0.007	5.820	(0.026, 0.053)
MATH				
BEHAVIOR				
INTENTION				
CONTROL	0.006	0.002	3.942	(0.003, 0.009)
Direct				
MATH				
CONTROL	-0.411	0.034	-12.181	(-0.477, -0.34)
Effects from INTENTION to MATH				
Total	0.026	0.006	4.109	(0.013, 0.038)
Total indirect	0.026	0.006	4.109	(0.013, 0.038)
Specific indirect				
MATH				
BEHAVIOR				
INTENTION	0.026	0.006	4.109	(0.013, 0.038)

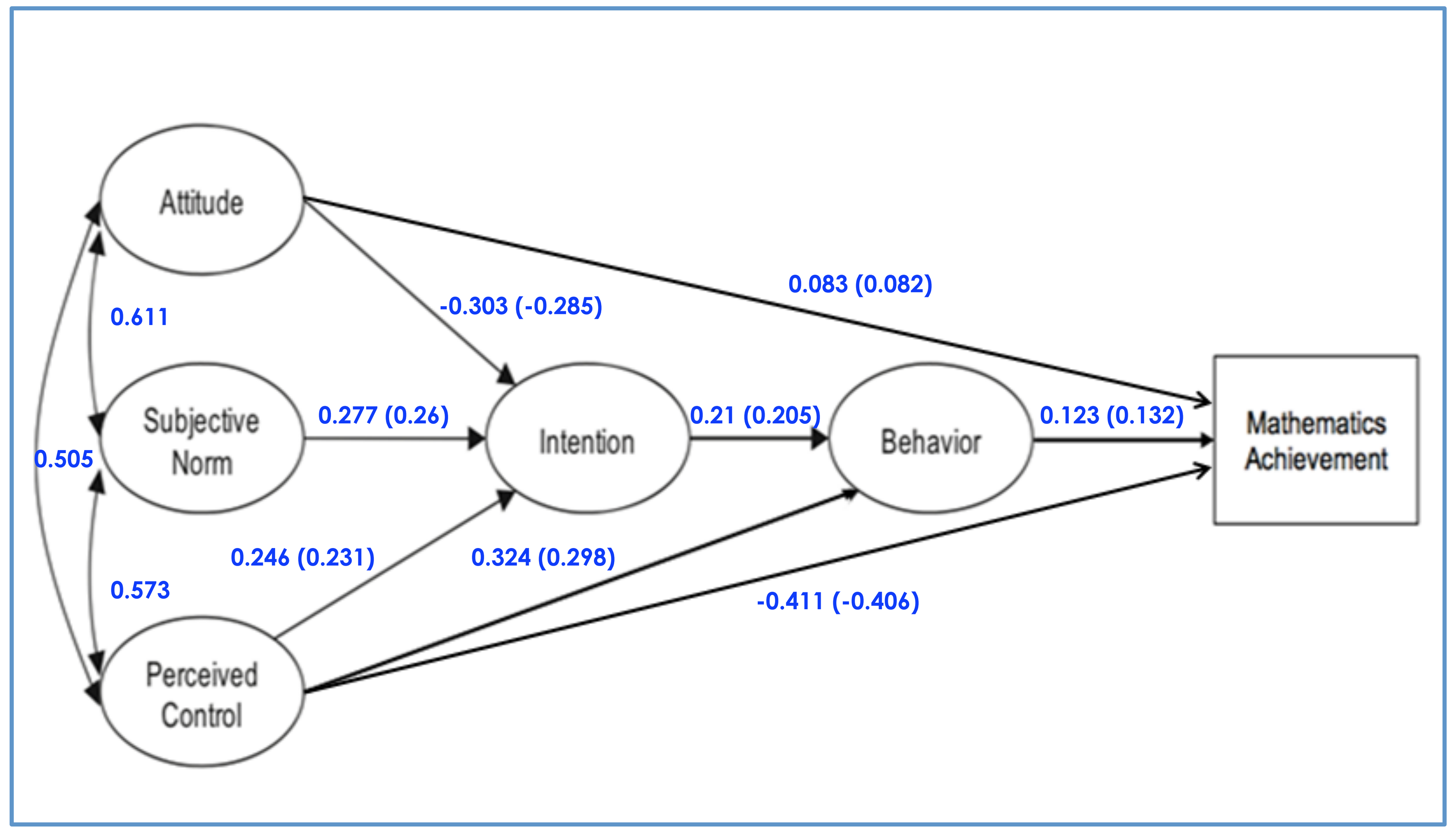
Note. Results reported are unstandardized. All results are statistically significant; $p < 0.01$. RMSEA statistic = 0.049, 95% CI [0.047, 0.051]

Next Analytic Steps

Multiple Groups. The dataset to be used for this analysis is the PISA 2012 student-level data, which measures the academic competency of 15-year-old students across several countries. The academic competency domain of interest is mathematics, which was the focal subject area in the 2012 PISA. The 13 countries of interest that will be examined are: Finland (n = 8,829), Canada (n = 21,544), New Zealand (n = 4,291), Australia (n = 14,481), the Netherlands (n = 4,460), Shanghai China (n = 5,177), Korea (n = 5,033), Hong Kong China (n = 4,670), Singapore (n = 5,546), and Japan (n = 6,351). These countries have historically been the highest performing in PISA assessments. The analysis will also include data from the United States (n = 6,111), the United Kingdom (n = 12, 659), and Germany (n = 5,001). Sample sizes reflect the number of students with valid data (unweighted) for performance in mathematics and problem solving. Three additional countries—the United States, the United Kingdom, and Germany were included because many educational theories have been developed and validated on samples that come from these countries (countries not among the top 10 performers but their average scores were higher than OECD average). For the United States Sample, the model will be replicated to predict to the additional four plausible values of mathematics achievement and the average of the estimates will be accepted.

Model Invariance. The TPB framework with the additional relationships towards mathematics performance will be tested across different countries by asking the following research questions: (1) Does the same overall model fit across all groups? (2) Does the model have the same values of some / all parameters across all countries? For this question, some model constraints may need to be executed. Further research interests include grouping countries of similar education systems (amount spent per student for public education) and socialization systems (Eastern v Western countries).

Results



Note. Coefficients reported in parentheses are standardized and all coefficients are significant at $p < 0.01$.

Interpretations: How are non-cognitive factors related to mathematics achievement?

The TPB framework fits the PISA data and the structure of the framework is supported by the results. The coefficients between intention and each of the following factors, attitude (b = -0.303, $p < 0.01$), subjective norm (b = 0.277, $p < 0.01$), and perceived control (b = 0.246, $p < 0.01$), is significant. The relationship between intention and behavior is also significant, b = 0.21, $p < 0.01$. The total indirect effect of perceived control on behavior through intentions, is also significant, b = 0.052, $p < 0.01$, 95% CI (0.036, 0.067). These results provide more support for the theory as it is applied in mathematics-related behavior using a large, nationally-representative dataset.

All direct and indirect effects in the TPB model predicting to math-related behavior are significant. More specifically, the TPB framework explains 9.78% of the variability in mathematics performance; R^2 = 0.978. The direct effects from the non-cognitive constructs of student attitudes and student perceived control on mathematics achievement are statistically significant; b = 0.083, $p < 0.01$ and b = -0.411, $p < 0.01$, respectively. The directions of these relationships suggest that positive attitudes towards school (such as indicating that school is important for future careers and college success) as well as an indication that students have control over their math-performance outcomes (such as agreeing with statements that they can succeed with enough effort) lead to a better understanding of mathematics performance that is not solely reliant on cognitive factors, which have been the dominant approach in the field of educational psychology.