GENDER DIFFERENCES IN ATTITUDES TOWARDS MATHEMATICS AND STEM MAJOR CHOICE: THE IMPORTANCE OF MATHEMATICS IDENTITY

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The building of a diverse and highly capable population of young people for careers in the science, engineering, technology, and mathematics (STEM) fields remains a critical issue in the United States. The researchers employed data from a nationally representative sample of high schoolers to better understand the relationships between students' learning experiences, attitudes towards mathematics, and STEM major choice. The focus of this paper is on how these relationships differ for males and females. The findings suggest that the underrepresentation of female students in STEM majors can be partially explained by a tendency for females to have less positive attitudes towards mathematics as compared to their male counterparts. Mathematics identity may be the most important attitude explaining this difference.

Keywords: STEM, Attitudes, Equity and Diversity, Gender

This research is part of a larger project aimed at better understanding factors that motivate U.S. students' decision to major in STEM fields and ultimately guiding efforts for broadening participation in STEM. The focus of this paper is on gender differences in attitudes towards mathematics and how these differences can help to explain why female students are underrepresented in STEM majors. Expectancy-value theory and data from the High School Longitudinal Study of 2009 were employed.

Theoretical Framework

The expectancy-value model of motivated behavioral choice (Eccles, 2009) holds that students' achievement-related choices (such as college major choices) are directly determined by the expectancy for success and the subjective value they attach to the tasks involved in those choices. Expectancy for success is similar to the notion of *self-efficacy* (Wigfield & Eccles, 1992). Subjective task values include the following three aspects: the relation of the task to one's self-image (*identity value*); the anticipated enjoyment from engaging in the task (*interest value*); and the perceived usefulness of the task for fulfilling personal goals (*utility value*). *Cost* is a fourth aspect of value that will not be examined in this study. Expectancies and values themselves are determined by various factors, including personal background characteristics and past learning experiences (Eccles et al., 1983). This model guides the research questions for the current study: (a) How are U.S. high school students' prior educational experiences, mathematics expectancy-value attitudes, and STEM major choice related? (b) How do these relationships differ for males and females?

Methodology

To answer these questions the present study employed data from the High School Longitudinal Study of 2009 (HSLS:09; Ingles et al., 2011). HSLS:09 is the most recent in a series of surveys administered by the National Center for Education Statistics (NCES) that follow nationally representative samples of young people as they transition from high school to postsecondary years. The first wave of HSLS:09's data collection began in the fall of 2009 with over 23,000 ninth-graders from 944 public and private schools throughout the United States. Sampling involved a complex, two-stage design in which eligible schools were first randomly selected and then students within those schools were randomly selected (Ingles et al., 2011). The students were followed up in the

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spring of 2011, when most were in the eleventh grade (Ingles et al., 2014) and a third time in 2013, after most had completed high school (Ingles et al., 2015).

Variables

The present study utilized variables from the base-year, first follow-up, and 2013 update of HSLS:09's public-use data file. Ninth-grade variables included mathematics achievement, STEM extracurriculars, and mathematics teacher support. Eleventh-grade variables included mathematics expectancy-value attitudes. The twelfth grade-variable was STEM major choice.

STEM major choice. STEM major choice was measured with a dichotomous variable indicating whether the student was planning to major in a STEM field at a postsecondary institution (reported in 2013 college update). Majors considered STEM included computer, physical, and natural sciences; engineering; mathematics and statistics; and military and science technologies/technicians.

Mathematics self-efficacy. Four items were used to measure students' confidence in their mathematics ability, including the degree to which they were confident that they can do an excellent job on tests and assignments; understand the most difficult material presented in the textbook; and master skills in their first follow-up mathematics course. All mathematics attitudes were standardized (mean = 0, SD = 1).

Mathematics identity. Two items were used to measure students' mathematics identity value, including the degree to which they agreed that they were a math person and other people saw them as a math person.

Mathematics interest. Five items were used to measure students' mathematics interest value, including the degree to which they agreed that their first follow-up mathematics course was enjoyable, a waste of time (reverse coded), and boring (reverse coded); that they were taking the classes because they enjoy math; and whether math was their favorite school subject.

Mathematics utility. Three items were used to measure student's mathematics utility value, including the degree to which they agreed that what they were learning in their mathematics course would be useful for everyday life, college, and a future career.

Mathematics achievement. Prior achievement in mathematics was measured using the ninth-grade algebraic reasoning assessment score. The assessment was developed by NCES using an item-response theory (IRT) design and standardized (mean = 0, SD = 1).

STEM extracurriculars. Extracurricular participating in STEM-related activities were measured by the number of mathematics or science related activities (clubs, summer camps, competitions, study groups) the student reported participated in from the base-year to the first follow-up.

Mathematics teacher support. Nine items were used to measure students' perceived support from their ninth-grade mathematics teacher. Some example items include the degree to which the student agreed that their teacher values and listens to students' ideas; thinks every student can be successful; and makes math interesting. This scale was also standardized.

Covariates. Covariates included student's gender (1 = female, 0 = male), race/ethnicity (1 = underrepresented minority [URM], 0 = white or Asian), and socioeconomic status.

Missing Data

Missing data were handled using multiple imputation. In total, five datasets were imputed for the analysis using Blimp 1.1 (Keller & Enders, 2018). The five datasets were analyzed and then the estimates and standard errors were averaged into a single set of results (Rubin, 1987). Multiple imputation has been shown to be robust against departures from normality and to provide unbiased results even for high rates of missing data (Enders, Keller, & Levy, 2018).

Analytic Plan

To analyze the relationship between the variables, the researchers used structural equation modeling (SEM; Byrne, 2011). The analysis was conducted in Mplus 8.2 with robust maximum likelihood (MLR) estimator and logit link. (Muthén & Muthén, 1998-2017). Figure 1 displays the path model. To asses model fit, the chi-square statistic (χ^2), comparative fit index (CFI), Tucker–Lewis index (TLI), and the root mean square error of approximation (RMSEA) were used. SEM literature typically considers CFI and TLI values greater than .95 and .90 to indicate excellent and acceptable fits, respectively. For RMSEA, values less than .05 and .08 are considered excellent and acceptable fits, respectively (Byrne, 2011). Design effect adjusted weights were applied to account for the nested structure of the survey (Hahs-Vaughn, 2005). As per Ingles et al. (2015), the raw weight adjusted was W3W1W2STU.

Results

The sample was comprised of 50.4 percent male and 49.6 percent female. The proportion of students who pursued STEM was 14.7 percent. Males chose STEM at a 19.4 percent rate compared to 9.9 percent for females. Whites and Asians chose STEM at a 17.5 percent rate compared to 11.2 percent for URMs. The (unweighted) sample size was N = 15,860 consisting of students who participated in the base-year, first follow-up, and 2013 update.

The SEM analysis began by testing the measurement model. The CFA indicated excellent fit of the measurement model: $\chi^2(217)$ = 2,898.685, CFI = .958, TLI = .951, RMSEA = .023. The CFA estimated that all four of the mathematics attitudes were significantly pairwise correlated ($p < .001$). However, examining variance inflation factors (VIFs) did not provide evidence of significant multicollinearity (VIF < 5). Next, the SEM model from personal background and educational experiences to mathematics attitudes was tested. This model also had adequate fit: $\chi^2(312)$ = 3,820.444, CFI = .951, TLI = .942, RMSEA = .022. Lastly, the full SEM model was tested. The above fit statistics are not available for models with categorical outcomes (Muthén & Muthén, 1998-2017). The pseudo R^2 for the logistic regression on STEM was .267.

Table 1 contains the estimates for the direct effects of personal background and prior educational experiences on mathematics attitudes. Table 2 contains the estimates for the direct, indirect, and total effects for the full path model, including the odds ratios (OR) for the direct effects on STEM major choice.

Table 1: Direct Effects for Paths from Educational Experiences to Mathematics Attitudes

	On Math Attitudes			
Predictor and Covariate	Self-Efficacy	Identity	Interest	Utility
Educational Experiences				
Math achievement	.23***	.39***	.24***	.11***
STEM extracurriculars	.14***	.14***	.15***	.10***
Math teacher support	.09***	.05**	.08***	.10***
Personal Background				
Female	-.25***	-.21***	-.11***	-.09***
URM	-.09	.07***	-.02	-.11***
SES	.33***	-.03**	.30***	-.11***

Table 2: Direct, Indirect, and Total Effects for Paths from Educational Experiences to Mathematics Attitudes and STEM Major Choice

	On STEM Major Choice		
Predictor and Covariate	Direct [Odds Ratio]	Indirect	Total

Educational Experiences			
Math achievement	.58*** [1.79]	.16***	.74***
STEM extracurriculars	.16*** [1.17]	.08***	.24***
Math teacher support	-.03 [0.97]	.04***	.01
Mathematics Attitudes			
Math self-efficacy	.11 [1.12]	—	—
Math identity	.31*** [1.36]	—	—
Math interest	-.01 [1.00]	—	—
Math utility	.16** [1.18]	—	—
Personal Background			
Female	-.77*** [0.46]	-.11***	-.88***
URM	-.09 [0.92]	.07***	-.02
SES	.33*** [1.39]	-.03**	.30***

Focusing on the first research question, Table 1 shows that the analysis found that higher mathematics achievement in ninth, participation in a greater number of STEM extracurriculars, and greater teacher support early in high school predicted more positive attitudes towards mathematics later in high school ($p < .001$ for all paths expect math teacher support on math identity which had $p < .01$). In turn, higher mathematics identity and utility predicted greater odds of majoring in STEM (OR = 1.36, $p < .001$ and OR = 1.18, $p < .01$ respectively).

For the second research question, Table 2 shows that after accounting for race/ethnicity, SES, prior educational experiences, and attitudes towards mathematics, females' odds of choosing a STEM major where half that of males (OR = 0.49, $p < .001$). From Table 1, the effect of female was negative on each mathematics attitude ($p < .001$ for all four), with the largest magnitudes on self-efficacy and identity. Thus, after accounting for personal background and prior educational experiences, female students tended to have less positive attitudes towards mathematics.

Discussion

This study provides evidence representative at the national scale for the expectancy-value model: higher mathematics achievement, greater participation in STEM-related extracurriculars, and more supportive mathematics teachers early in high school predict more positive attitudes towards mathematics later in high school, which in turn predict greater odds of majoring in STEM. The findings suggest that the underrepresentation of females in STEM in the U.S. can be partially explained by less positive attitudes towards mathematics with a sense of identity as a math person having the largest gender disparity. Given that mathematics identity was also the attitude most predictive of STEM major choice, this study supports the growing focus on identity in mathematics education research (see Graven & Heyd-Metzuyanim, 2019). Future work for this project is planned to better understand why female students' attitudes towards mathematics tended to be lower than that of males. Existing literature suggests that negative stereotypes about STEM professionals are partially responsible, including unattractive appearances and socially awkward personalities, which are typically at odds with female gender identity and cultural expectations (Eccles & Wang, 2016; Starr, 2018).

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