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The Effect of Mathematics Self-Efficacy on Mathematics Achievement of High School Students

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Introduction

Self-efficacy is an important concept in social cognitive theory, which has been widely recognized as one of the most prominent theory about human learning (Ormrod, 2008). First developed by Albert Bandura (1977; 1986), self-efficacy refers to learners' beliefs about their ability to accomplish certain tasks. Many researchers, including Bandura, have demonstrated that self-efficacy affects human motivation, persistence, efforts, action, behavior, and achievement (Bandura, 1977, 2000; Zimmerman, Bandura, & Martinez-Pons, 1992). Researchers have indicated that higher self-efficacy is predictive of higher performance (Bong & Skaalvik, 2003).

Because there are subtle differences between self-efficacy and attitude, it is important to distinguish between these two terms. As stated above, self-efficacy is a person's self-confidence about their ability to accomplish a task. Attitude is a person's feelings about a task, such as whether or not they believe the task is important, enjoyable, or difficult (Aiken, 1974; Fennema & Sherman, 1976; Tapia & Marsh II, 2004). Students with positive attitude may believe that mathematics is important to their everyday world or solving mathematics problems is enjoyable. Even though they may believe that mathematics is important they may not believe that they can solve a math problem. That means a person with a positive attitude may have a low self-efficacy. On the contrary, if they believe that mathematics is important they may develop persistence toward mathematics and eventually develop a higher self-efficacy.

A search of mathematics education research indicates that several studies have been conducted on the relationship between attitude toward mathematics and achievement in mathematics (Ma, 1997; Ma & Kishor, 1997; Ma & Xu, 2004). Ma (1997) examined the reciprocal relationship between attitude toward mathematics and mathematics achievement using the data from the Dominican Republic. The findings suggested that the reciprocal relationship existed between attitude toward mathematics and mathematics achievement. In addition, enjoyment of mathematics directly affected mathematics achievement, and the feeling of difficulty indirectly affected mathematics achievement. Ma and Xu (2004) investigated the causal ordering between attitude toward mathematics and mathematics achievement using structural equation modeling. The results indicated that all but one path from prior attitude to later achievement was significant, with the standardized path coefficients ranging from .03 to .13. Additionally, the paths from prior mathematics achievement to later attitude toward mathematics were all significant, with the standardized path coefficient ranging from .11 to .23. These studies found that attitude toward mathematics was a significant predictor of mathematics achievement, and furthermore, the causal relationship between them was identified.

Although numerous studies have been conducted on the relationship between attitude toward mathematics and mathematics achievement, comparatively there was a deficiency of research in examining the relationship between mathematics self-efficacy and mathematics achievement. Further, no research has been conducted using large-scale samples across the nation.

Randhawa, Beamer and Lundberg (1993) investigated the role of mathematics self-efficacy in mathematics achievement using structural equation modeling.

Mathematics Self-efficacy Scale (MSES) was used to measure students' confidence level in completing mathematics courses, solving mathematics problems, and dealing with everyday mathematics-related tasks. Results indicated that mathematics attitude had both direct and indirect effects on mathematics achievement, but self-efficacy was a mediator variable between mathematics attitude and mathematics achievement.

The purpose of our study was to investigate the relationship between mathematics self-efficacy and mathematics achievement of high school sophomores across the United States using regression analysis for complex sample survey data. Specifically, the following research questions were addressed: (1) Was there a significant relationship between mathematics self-efficacy and mathematics achievement; If yes, how large was the correlation coefficient? (2) Could mathematics achievement of high school sophomores be significantly predicted by their mathematics self-efficacy?

Methods

Sample

The base-year data from the Educational Longitudinal Study of 2002 (ELS, 2002) was used for the analyses. The ELS: 2002 study, conducted by the National Center for Educational Statistics (NCES), was designed to provide longitudinal data regarding the transitions of 2002 high school sophomores to postsecondary school education and their future careers. In the 2002 base year of the study, more than 15000 high school sophomores, from a national sample of 752 public and private high schools, participated in the study by taking cognitive tests and responding to surveys. These 752 schools represented the approximately 25000 public and private schools in the United States that had a 10^{th} grade in 2002; the sample students represented approximately three million

10th graders in the United States attending schools in 2002. The 2002 base year sophomore cohort was followed at two-year intervals.

ELS: 2002 used a two-stage sampling design. First, using a stratified sampling strategy, 1221 eligible public and private schools were selected from a population of approximately 25000 schools with 10th grade students. Of these eligible schools (clusters), 752 agreed to participate in the study. Second, in each of those schools, approximately 25 students in 10th grade were randomly selected from the enrollment list.

The stratified sampling was used to select primary sampling units (PSUs), i.e., schools. The sampling frame for public schools was stratified by nine geographic areas (defined by the U.S. census) with each area corresponding to several states. For example, the New England/Middle Atlantic area includes the states of CT, ME, MA, NH, NJ, NY, PA, RI, and VT. Rather than using nine areas as strata for sampling public schools, Catholic and other private schools were sampled by the four-level Census regions (i.e., Northeast, Midwest, South and West), with each regional strata including its corresponding states.

Weights were used to compensate for differential probabilities of selections of schools and students, and to adjust for the effects of nonresponse because not all schools and students who were selected in the sample actually participated in the study. For the base year (2002) cohort, a base year analysis weight, also called the final weight, BYSTUWT, was used in the following analyses.

In the following data analysis, the sample size of the study was 11726 high school sophomores from 748 schools (PSUs) and 361 strata after the listwise deletion was used.

Instrumentations

A survey instrument, *Student Questionnaire Base Year: 10th Grade*, was used by the ELS: 2002 study to mainly measure high school sophomore students' perceptions of school experiences and activities, obtain their values and goals for the future, assess their English speaking ability, collect information regarding parents' education and family support, and the task value and self-efficacy of mathematics and reading. In the section of beliefs and opinions about self, five items related to mathematics self-efficacy were identified from the instrument. For the mathematics self-efficacy subscale, participants were asked to select one response on a four-point Likert scale ranging from almost never (1) to almost always (4) (See Table 1).

Insert Table 1 around here

The Math IRT (item-response theory) score was used to measure mathematics achievement. The mathematics tests, including items in arithmetic, algebra, geometry, data/probability and advanced topics, focused on practical applications and problems solving. This score was an estimate of the number of items students answered correctly when they responded to all 72 items in the ELS: 2002 mathematics tests.

Data Analysis

An exploratory factor analysis (EFA) was conducted to examine the construct validity of mathematics self-efficacy scale. A reliability analysis for the scale was also conducted. Because the ELS: 2002 study used complex survey sampling designs which involved the use of different strata (minority groups), clustered sampling techniques, and unequal selection probabilities, it is inappropriate to conduct regression analyses without taking the survey sampling design into account. Failing to do this will lead to biased estimates of parameters and incorrect variance estimates, and thus the misleading results.

Although structural equation modeling (SEM) can be used to address our research questions, current software packages do not have the function of conducting the SEM analysis by taking the design features into account. Among a few of statistical software packages which can perform statistical analyses within the context of survey sampling designs, Stata (V. 10.0) is a promising tool to deal with this issue. The latest version of Stata can perform analyses for complex survey data with 48 statistical models using its svy prefix command (StataCorp, 2007).

SPSS (V. 15.0) was used for the exploratory factor analysis and reliability analysis of the mathematics self-efficacy scale. SPSS was also used for the descriptive statistics and correlation analyses. Stata 10.0 was used for the regression analysis of the complex sample survey data. Stata *svyset* command was employed to specify complex sampling designs including strata, primary sampling units (PSUs), and weights. The *svy: regress* command was employed for the survey regression analysis. The linearization method (Taylor series approximation) was used to estimate the sampling variance in survey regression analysis.

Results

Exploratory Factor Analysis Results

An exploratory factor analysis (EFA) was conducted to examine the factorial validity of the 5-item instrument using SPSS 15.0. Principal axis factoring and the oblimin rotation methods were used in the EFA. Univariate statistics, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, Bartlett's test, communalities, eigenvalues, and the scree plot were examined.

The KMO for the sample data was found to be .879, suggesting that the correlations among items is good for conducting factor analysis (Tabachnick & Fidell, 2007). For the Bartlett's test of sphericity, $\chi^2 = 43469.25$, df =10, p<.001, indicating that the correlation matrix among the items was not an identity matrix.

All the initial communalities were larger than .66, and all the extracted communalities were larger than .69, indicating that shared variation among the collection of items was at a good level for factor analysis.

In the factor analysis, one factor was extracted on the basis of the eigenvalue larger than one criterion. The rotation eigenvalue for the first factor was 3.680, indicating 73.603% of total variance in all the items was accounted for by that factor. Considering the extracted communalities were high, this result indicated that much of the variance in the items could be explained by the one extracted factor. The scree plot also suggested that one-factor solution since only one factor could be retained above the elbow of eigenvalues. All the five items loaded on the one extracted factor, and all the factor loadings were high, ranging from .835 to .875.

These results indicate that all these items represented the underlying factor, mathematics self-efficacy. Therefore, the five-item one-factor pattern was the most interpretable factor pattern.

Reliability Analyses

Based on the results of EFA, a reliability analysis was conducted on the five items in the mathematics self-efficacy scale. The reliability coefficient (Cronbach's alpha) of mathematics self-efficacy was .933, indicating a high internal consistency among the items of this factor. In addition, the average inter-item correlation was .736 and the standard deviation of inter-item correlations among the scale was .141, which were both acceptable.

Descriptive Statistics and Pearson Correlations

Table 2 presents the results of descriptive statistics and the correlation coefficient from the correlation analysis. As indicated in the table, mathematics self-efficacy was statistically associated with mathematics IRT score ($r = .362$, $p < .001$).

Insert Table 2 around here

Regression Analysis for Complex Sample Survey Data

Stata 10.0 was used for analyzing the ELS: 2002 data with the complex sampling designs by taking weights, strata and clusters into account. The survey linear regression analysis was used to predict mathematics achievement of 10^{th} grade students on mathematics self-efficacy (n= 11726, strata = 361, and PSU =748). The independent variable, mathematics self-efficacy provided a statistically significant explanation of variance in mathematics achievement, $R^2 = .129$, $F(1,387) = 970.28$, $p<.001$. In survey regression analysis, the degree of freedom equals the number of PSUs minus the number of strata minus the number of independent variables plus one. In this analysis df = 748-361-1+1 = 387.

The regression equation is: Y-hat = 25.543+ 5.091 (Self-efficacy). Table 3 presents the parameter estimates, linearized standard errors, one-degree of freedom t-test for the independent variable in the model. The beta weight suggested that mathematics IRT score increased as students' mathematics self-efficacy increased. $R^2_{adj} = .129$, indicating that 12.9% of the total variance in mathematics achievement was explained by the model.

Insert Table 3 around here

Discussion

The purpose of the study was to better understand the relationship between mathematics self-efficacy and mathematics achievement of 10^{th} grade students, and to investigate whether mathematics achievement could be significantly predicted by mathematics self-efficacy. A correlation analysis and a survey linear regression analysis were used to address the research questions.

Results of the correlation analysis indicated that mathematics self-efficacy and mathematics achievement were positively related. Students with high mathematics self-efficacy were associated with high mathematics achievement. Additionally, results of the survey linear regression analysis indicated that mathematics achievement could be significantly predicted by mathematics self-efficacy. Mathematics self-efficacy was a significantly positive predictor of mathematics achievement. This finding suggests that students who were confident of their performance in mathematics tended to have better mathematics achievement. Specifically, students who were confident that they could do an excellent job on math tests, they could understand the most difficult material presented in math texts, they could understand the most difficult material presented by their math teachers, they could do an excellent job on math assignments, and they could master the skills being taught in their math classes, were more likely to have better mathematics achievement.

Educational Implications

This study provides empirical evidence of the effect of mathematics self-efficacy on mathematics achievement among high school sophomores across the United States. Results from this study can be generalized to the population of approximately three million high school sophomores. Compared to the standardized effect of attitude toward mathematics on mathematics achievement in prior research (Ma, 1997; Ma & Kishor, 1997; Ma & Xu, 2004), the effect of mathematics self-efficacy (standardized coefficient = .36) identified in this study was much stronger. This finding suggests that in addition to promote students' attitude toward mathematics it is more important to promote their self-efficacy in order to enhance achievement in mathematics.

Our findings also suggest that efforts are needed for promoting mathematics self-efficacy for high school students because mathematics self-efficacy was positively associated with mathematics achievement. Research has indicated that self-efficacy could be increased by using the right instructional strategies (Schunk, 1991; Siegle & McCoach, 2007), such as helping students to set learning goals (Bandura, 1997; Schunk, 1991), providing timely and explicit feedback (Bandura, 1997), encouraging students to study harder (Siegle & McCoach, 2007), and using high achieving students as models (Bandura, 1986; Schunk, 1991; Siegle & McCoach, 2007).

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Table 1

Items of the Mathematics Self-Efficacy

Section 1: Mathematics Self-Efficacy
1. I'm confident that I can do an excellent job on my math tests.
2. I'm certain I can understand the most difficult material presented in math texts.
3. I'm confident I can understand the most difficult material presented by my math teacher
4. I'm confident I can do an excellent job on my math assignments
5. I am certain I can master the skills being taught in my math class.

Table 2

Descriptive Statistics and Correlations among the Measured Variables (n=11726)

Variable	M	SD	1	2
1. Mathematics IRT Score	39.073	11.881	--	.362**
2. Mathematics Self-Efficacy	2.520	.844		--

Note. ** $p < .001$.

Table 3

Results of the Survey Linear Regression Analysis for Self-efficacy Predicting Math Achievement (n= 11726, strata = 361, and PSU =748)

Variable	b	Linearized SE	t	p
Constant	25.543	.438	58.32	----
Self-Efficacy	5.091	.163	31.15	<.001

Note. R^2=.129; F(1,387) = 970.28, p<.001