Proceedings of the 9th WSEAS International Conference on Applied Mathematics, Istanbul, Turkey, May 27-29, 2006 (pp242-249)

The Role of Mathematics self-efficacy and Mathematics ability in the structural model of Mathematics performance

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Abstract—The purpose of present study was to examine the direct and indirect effects of mathematics ability on mathematics Performance, specially, with regarding to powerful predictor and mediator of mathematics self-efficacy. 848 of 8th graders were randomly selected from two educational districts of Yazd province (Iran) to estimate and test the hypothesized effects of mathematics ability on mathematics self-efficacy and Performance. In usage of three latent variables were acknowledged with confirmatory factor analysis. Then the estimate of structural equation model revealed that mathematics ability had a direct and a indirect effect (Via mathematics self-efficacy) on mathematics performance. The model specified mathematics ability and mathematics performance. A substantial proportion of variance (50%) in mathematics performance was predicted from the model. The high goodness-of-fit indices, also acknowledged that postulated model has a good fit to the data. These findings in line with other works support the hypothesized role of self-efficacy in Bandura (1986) Social cognitive theory.

Keywords—Mathematics self-efficacy, Mathematics ability, structural model, Mathematics performance

1. Introduction

The National Research Council (1989) warranted that the mathematics skills of many students, not just those with learning difficulties, fall well short of what is required in the workplace. Support for this claim has come primarily from National Assessment of Educational, Associational Progress (NAEP) (1992) that only about half of 12th grade student could demonstrate facility in problem solving beyond whole number computation. The Third International Mathematics and Science Study (Beaton et al, 1996) indicated that U.S 8th – grade students ranked 18 among students in 25 countries in math achievement. In light of the prominent role of mathematics among subjects in school, it is not surprising that math educational and psychological research has been devoted to the identification of factors that enhance the learning and teaching of mathematics (e.g.Grows, 1992).

According to Bandura (1986), individuals possess a self-system that enables them to exercise a measure of control over their thoughts, feelings and actions. In this view, self-referent thoughts mediate between knowledge and action. Through self-reflection process individuals can evaluate their own experiences and thought processes. However individual interprets the result of their performance and alters their environments and their self-beliefs, which in turn informs and alters their subsequent performances.

Bandura introduced self-efficacy beliefs as a key concept of his theory and defined it as a personal Judgment of one's capabilities to organize and execute courses of action to attain designated goals. This Judgment strongly influences the choices of people make, the effort they expend, and how long they persevere in the face of challenges (Bandura, 1986).

Several studies have shown the viability of self-efficacy in situation in which self-efficacy perception of a specific task significantly related to subsequent performance on a similar task (Bandura, 1977, 1986; Hackett, Betz, O'hallaran & Romance, 1990; Norvich, 1985).

In academic settings Self-efficacy research has primarily focused on two major. One area has explored the link between efficacy beliefs and college major and carrier choices, particularly in the area of science and mathematics (e.g., Bores- Rangel, church, Szendre, & Reeves, 1990; Brown, Lent & Larkin, 1989; Farmer. Wardrop, Anderssn & Risinger,1995). Researchers have reported that the mathematics Self-efficacy of college undergraduates is more predictive of their mathematics interest and choice of math-related courses and majors than either their prior math achievement or math outcome expectations (Hackett, 1985, Hackett & Betz, 1989, Lent, Lopeze, Bieschke, 1991,1993, Pajares and Miller, 1994,1995 b). Studies in the second area have investigated the relationship among efficacy beliefs related psychological constructs and academic motivation and achievement. Self- efficacy has been prominent in studies that have explored its relationship with problem solving (Bouffard- Bouchard, 1989, Larson, Piersel, Imao & Allen, 1990), self-regulation (Bandura, 1991 Shunk, 1982 a), and strategy training (Schunk & Cox, 1985).

Math self- efficacy had been shown to be as strong predictor of mathematical problem- solving capability as general mental ability (Pajares & Kranzler 1995), a variable generally found to be a powerful predictor of academic performance (Thorndike, 1986).

In the area of mathematics performance, various researchers (pajares, 1996; Pajares & Miller, 1994) have reported that student judgment of their capability to solve mathematics problem are predictive of their actual capability to solve those problems. These judgments also mediate the influences of other predictive such as math background, math anxiety, and perceived usefulness of mathematics, prior achievement and gender. Hackett and Betz (1989) defined mathematics self- efficacy "as a situational or problem- specific assessment of an individual's confidence in her or his ability to successfully perform or accomplish a particular (mathematics) task or problem" (p.262).

Moulton et. al (1991) found 36 studies written (between 1977 and 1988) on the relationship between self-efficacy and academic performance and persistence that met their criteria for inclusion in a meta analysis. They computed efficacy beliefs were related to performance ($r_{sub}u$=0.38) and accounted for approximately 14% of the variance in academic performance. Schunk (2000) also suggested that self-efficacy beliefs could predict over the 25% of academic performances (even more than instructional treatment of effects).

In the field of mathematics achievement, several studies used structural education modeling or path analysis for determining the important variables that effect mathematics performance directly or indirectly via mathematics self- efficacy.

Pajares and Kranzler (1995a, 1995b) constructed path models included math self-efficacy, general mental ability, math self-concept, math anxiety, self-efficacy for self-regulation, previous grades in mathematics and sex.

In another research Pajares (1996b) introduced more special major of ability, cognitive ability in a path model with other variable such as math anxiety, mathematics grades self-efficacy for self-regulation and sex too. In regular students model, cognitive ability had a significant direct effect on mathematics problem solving (β=0.242) and in gifted students model this variable effected on dependent variable via mathematics self-efficacy. Pajares and miller (1994) also suggested that exclusion of ability measures in mathematics model studies may have influenced the effects found and recommended that future model include an ability measure to testing of prior findings.

Although mathematical ability is sometimes treated as a single entity, it has been occasionally argued over many years (e.g. Weaver, 1954) that it is made of a number of components and there is an increasing evidence for that view for example studies of pre schoolers' counting (Greeno et. al, 1984) have given rise to the idea of a distinction between conceptual competence, understanding basic number concepts and counting principles, and procedural competence, being able to count accurately.

In mathematics achievements cognitive ability or mathematics ability are powerful variable that effect on mathematics performance directly or indirectly by mediating of self-efficacy mathematics.

Collins (1982) selected children who judged themselves to be of high or low efficacy at each of three level of mathematical ability. They were then given difficult mathematical problems to solve. Within each level of ability children who had the stronger belief in their efficacy were quicker to discard faculty strategies solved more problems, chose to rework more of those they failed and did so more accurately than children of equal ability who doubted their efficacy.

Bouffard-Bouchard, Parent and Laree (1991) demonstrated that regardless of weather children were of superior or average cognitive ability, those with a high sense of efficacy were more successful in solving conceptual problems than were children of equal ability but lower perceived efficacy. Children with the same level of cognitive skill development differ in their intellectual performance depending on the strength of their perceived efficacy.

2.1 Proposed Model

Drawing upon the theoretical literature of self-efficacy (Bandura, 1977, 1986) and the findings from the numerous students under review, we proposed a simple mathematics structural model with mathematics ability and mathematics self-efficacy as independent variables for performance predicting.

We used LISREL 8.53 (Joreskog & Sorbom, 2002) to test a model in which mathematics ability directly and indirectly, by affection on mathematics self-efficacy, predicted mathematics performance of eighth graders.

A typical model of LISREL consists of two Parts: measurement model and structural equation model. The purpose of a measurement model is to describe how well the observed indicator serve as a measurement instrument of the Latent variable. The key concept here is measurement, reliability and validity. Then structural model or path analysis determines causal relations between Latent variables. This model illustrates the power of relations in terms of direct, indirect and total effects.

The consistency of estimated model with collected data examined by fit indexes. The most common indexes are chi square, goodness-of-fit index (GFI) and adjusted goodness-of-fit index (AGFI). Since chi-square test is sensitive to sample size violates the assumption of multivariate normality and thus, alternative fit indices such as the ratio of chi-square to the degree of freedom test and other fit indices such as comparative fit index (CFI) and Non-Normed fit index (NNFI) have been recommended (Bentler, 1983).

2. Method

2.1 Sample

The sample consisted of 848 (420 male and 428 female) eight-grade students from two educational districts of Yazd city (Iran). These students selected in random from 135 middle schools.

2.2 Measures

2.2.1 Mathematics performance test

This test consists of 15 open-ended items in five content areas of school text: Linear equation, algebra, geometry, arithmetic and vector. This test developed by expert mathematics teachers and then several stages of psychometric analysis, these item results from questions repertoire with 25 items. Selected item have difficult coefficients between 40 to 60 and item discriminating power up to 40. Content validity was confirmed by psychometric specialists and concurrent validity of this test with student's score of mathematics in first semester was 0.75.

The reliability of the test by 21 Kuder-Richardson formulas computed 0.93.

2.2.2 Mathematics self-efficacy Scale

Consistent with Banduras (1986) guidelines, the Problems on which self-efficacy was assessed must be the same as those on which Performance was measured. Thus accorded to Pajares's, Mathematics Self-efficacy Scale (MSES), the items of this questionnaire (15) was developed by cooperation of teachers group in same content area. Students indicated their confidence on an 11- point scale ranging from no confidence at all (0) to complete confidence (10).

These items also selected from item repertoire that have difficult coefficients between 30 to70 and item discriminating Power Up to 40 in Pilot Study. In addition_acknowledgment of content validity, the reliability of questionnaire was 0.92.

2.2.3 Mathematics ability Test

Accordance to Literature about componential of mathematics ability (Terston, 1974; Gary and Videman, 1992; and Grine etal, 1984) this test was developed in two subscales: Conceptual ability and strategically ability. These 14 items developed in four choice responses and Selected from different Tests: Graded Arithmetic's Mathematics Test (Vernon and Miller, 1976), Numerical ability of differential aptitude tests (Bennet, Seashore. and Wesman (1972) and questions Sample of giftedness mathematics exams. Difficult Coefficients of Selected item were between 40 to 60 and discriminating Power of to 40. Content Validity of Test acknowledged by expert math teachers and Statistics mathematics and Psychometric Professors of University. The reliability of these tests computed by 20 Kuder Richardson methods and revealed confident of 0.81. Subscales reliability coefficients was .083 for conceptual and 0.76 for strategical ability.

3. Results

Analysis was initially Conducted Means, Standard deviations and Covariance matrix. As the first Step these measures are presented in table 1.

Table1: Means, Standard deviations and Matrix covariance of observed variables

Variable	M	SD	1	2	3	4	5	6	7	8
1. Linear equation P.	2.4	1.7	0.19							
2. Algebra P.	2.8	1.6	0.12	0.15						
3. Geometry P.	2.3	1.5	0.16	0.14	0.24					
4. Arithmetic & Vector P.	3.1	1.6	0.13	0.12	0.14	0.17				
5. Composite Se	7.05	2.6	0.43	0.40	0.52	0.44	4.43			
6. Geometry Se	7.5	2.3	0.38	0.37	0.52	0.42	3.37	5.3		
7. Conceptual a	4.7	2.5	0.36	0.33	0.38	0.37	1.85	1.75	3.54	
8.Sterategical a	1.08	0.98	0.15	0.14	0.17	0.15	1.8	0.73	1.06	1.43

P: Performance, Se: Self-efficacy, a: Ability
Note: observed Variables of 1 to 4 are indicators of mathematics Performance, 5 and 6 are factors of mathematics Self-efficacy and 7 and 8 Variable are two Components of mathematics ability construct.

The Covariance matrix was used as introduced data to LISREL and Perform maximum likelihood linear Structural, relations' analysis to LISREL and Perform maximum likelihood linear Structural Relation's analysis.

3.1 Assessment of Measurement models

3.1.1 Mathematics Performance Test: The MPT was designed with five factors (Performance in: linear equation, Algebra, Geometry, Arithmetic and Vector). Confirmatory factor analysis was done as a first step to determine the adequacy of factor loading and model fit of MPT using LISREL 8.53 (Joreskog & Sorbom, 2002). All factor loadings for the MPT were statistically significant and the statistics for factor loadings were all greater than 1.96 and in the expected direction. It is necessary to note that the components of arithmetic's and vector loaded under one factor in explanatory factor analysis by orthogonal rotation.

Standard Parameters for each factors, in order 0.83, 0.87, 0.82 and 0.86, revealed that all indicators are Powerful Factors to assessment of mathematics Performance. Conventional fit Statistics include chi-square, Goodness-of-fit idea (GFI), adjusted goodness-of-fit index (AGFI). Measurement model of mathematics Performance according to Confirmatory analyses had accepted fit indexes Chi= 3.7, df=1, p> 0.05, GFI = 1, AGFI = 0.98 and RMSEA = 0.05. squared multiple correlation for MPT Variables revealed that this model can predicts in order 0.78, 0.80, 0.70 and 0.69 Variance of factors. Reliability coefficients of indicators also were 0.84, 0.83, 0.77 and 0.78.

3.1.2 Mathematics self-efficacy questionnaire: Although this instrument developed in parallel with MPT in contents and areas of item planning, but in explanatory factor analysis, this latent variable, introduced two factors in four content areas loaded under one factor (composite self-efficacy) and only geometry self-efficacy loaded under second factor independently. All of critical measures in factor analysis were significant.

With regard to two factorial of this variable, confirmatory factor analysis was conducted in second order analysis. For any factor, most important questions introduced as observed variables and confirmatory factor analysis conducted.

Standard parameters for each factors, items observed variables of two latent variables, were high and powerful factors to assessment of mathematics self-efficacy. Because the chi-square test is affected by model and sample size (Benther & Bonett, 1980), the suggestion of Byrne (2001) and McDonald and Ho (2002) was to use five measures fit to evaluate the data according to the proposed model: the chi-square/degree of freedom ratio, the GFI, the normal-fit index (NFI), the comparative-fit-index (CFI) and the expected cross validation Index (ECVI). These indecisive of this model were in ordinary: 0.206, GFI=0.99, NFI=1, CFI=1 and ECVI=0.055 that is smaller than ECVI for saturated model (0.59).All of these indecise indicated that two general factor and their indicators (items), are powerful factors to assessments of self-efficacy in mathematics.

According to squared multiple correlations for observed variables that introduced to LISREL model (three items for composite self-efficacy and three items for geometry self-efficacy), the extracted model of confirmatory factor analysts predicted in ordinary 0.67, 0.69, and 0.63 of first latent variable factors and 0.50, 0.71 and 0.70 of second latent variable factors. The reliability coefficients of two subscales were 0.92 and 0.78.

3.1.3 Mathematics Ability Test: This instrument consisted of two factors: conceptual and strategic ability in mathematics. Exploratory factor analysis consisted with literature acknowledged two factors under this latent variable. With regard to forced-choice format of this test, factor analysis conducted with pro-max method and all factorial loading of item under two factors and other measures where significant with regard to two factorial of this variables, confirmatory factor analysis of this test was conducted in second order analysis for any factors, most important questions introduced as observed variables (three item for concept ability and three item for strategic ability) and then confirmatory factor analysis conducted.

Standard Parameters for each observed variables were high and powerful enough to measure mathematics ability latent variable.

In addition to GFI and AGFI, according to Byrne (2001) and McDonald and Ho (2002) other fitting indexes also estimated for this measurement model. Goodness-of-fit indecise (GFI=0.99, AGFI= 90, Chi square/ df= 2.03, NFI=0.99, CFI=0.99 and ECVI =0.049 was smaller than ECVI for saturated model=0.05) where high and acceptable. All of these indecise revealed consistency of measurement model with collected data.

3.2 Assessment of structural Model

The structural equation model tested the hypothesis that mathematics ability effects on mathematics performance mediated by mathematics self-efficacy. Path coefficients of the modified structural model for total group are given in figure 1.

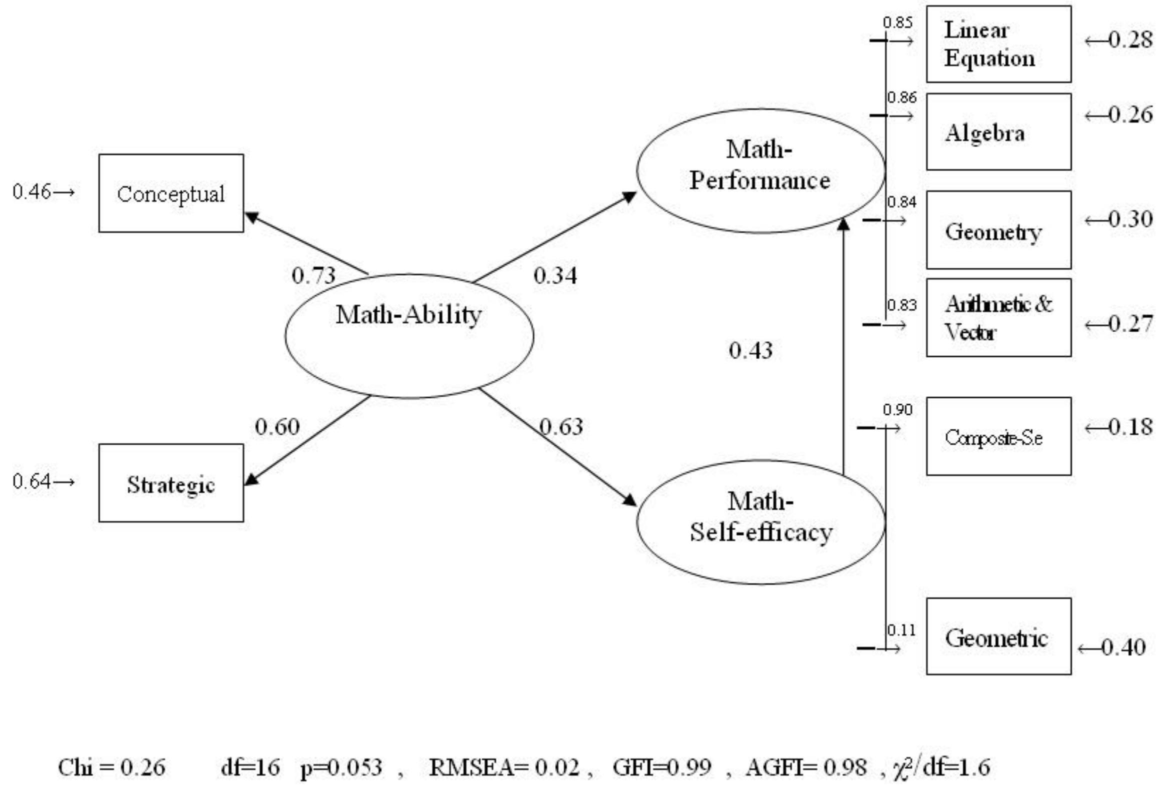

Figure 1: Completely standardized parameter estimates for the structural model of mathematics achievement.

Note: All the parameter estimates were significant (P<0.05) in terms of obtained values.

The results indicated that the overall model fit the data reasonably well. All the parameter estimates were significant (P<0.05) in terms of obtained values. The most important indexes were utilized as evidence of fit.

All of the path coefficients of latent variables in the structural model revealed that mathematics ability is a powerful indicator of mathematics self-efficacy and performance. The model explained 50% in mathematics performance and 38% in mathematics self-efficacy.

Mathematics ability had a direct effect (β=0.34) and indirect effect (β=0.27) on mathematics performance. The total effect of exogenous variable on dependent variable was 0.61. In addition mathematics self-efficacy had a direct effect (B=0.43) on mathematics Performance.

These coefficients revealed that the important part of relation between math ability and performance was explained by math self-efficacy. So with exclusion of this variable of model, explained variance of math performance decreased to 0.39.

In measurement's model of math ability, conceptual math ability was powerful and was the indicator of latent construct. In math self-efficacy and performance also in order composite of self-efficacy and performance in algebra with higher assessment of their variables.

4. Discussion

The purpose of this study was to discover the direct and indirect effects of mathematics ability on mathematics performance. According to social cognitive theory of Bandura (1986), investigating of mediation role of mathematics self-efficacy between math ability and math performance was other purpose of present study.

As MC Combs & Whisler (1989) cautioned in line with the Bandura (1986) confidence in doing a task and the confidence in ones ability in an area of endeavor are critical factor of motivation and Persistence. It is Possible that Perceptions of inefficacy in mathematics would lead learners to reduced level of motivation and lessen their engagement in math and in math related courses.

The finding of this study supported the hypothesis that influence of math ability on math-Performance was mediated by math-self efficacy and math-ability has a direct effect on math-performance.

These findings were in line with works of Bandura (1977, 1986) and Phillips & Gully (1997) who Postulated that the effect of ability on achievement mediated by self-efficacy and later finding (Phillips & Gully, 1997) that ability factor is a significant Predictor of self-efficacy in a structural model. In addition, findings of this study supported Bouffard-Bouchard et al (1991) in which individual's differences of students in mathematics performance mainly related to there difference in self-efficacy beliefs. Self-efficacious student could apply more effective strategies and have more perseverance on difficult problems and resist on frustration. Also Collins (1982) reported that ability was related to performance but those, regardless of ability level, children with high self-efficacy completed more problems correctly and reworked more of the one they missed.

In consistent with these results, when researchers (e.g.; Pajared & Kranslet (1995) tested the Joint continuation to mathematics performances of math self-efficacy and general mental ability (The variable typically acknowledged as the most powerful predictor of academic Performance), they found that despite the influence of mental ability, self-efficacy made a powerful independent contribution to the prediction of performance.

In spite of Dew, Galassi and Galassi (1984) math ability assessment in mathematics Performance structural models might confound by attitudinal and anxiety elements and in spite of Lent et.al (1991) claim that ability did not contribute significant incremental variance to the prediction of math course interest after controlling for self-efficacy, present study had conducted on recommendation of Pajares and Miller (1994): “We Would be remiss, however, if we did not acknowledge that its exclusion (ability measures) may have influenced the effects found, and we recommend that a future model include the ability to measure tester our findings."(p202).

The correlation between math ability and two dependent variable were significant at $P<0.01$. This basic finding had observed in other researches. Slife, Bell and Weiss (1985) revealed that a problem solver should be able to recognize, and evaluate, regulate resources in order to achieve goals. In acknowledgment of importance of strategic ability, they emphasize that learner's awareness of their learning processes can lead to controlling and monitoring those learning process. Also effective computational ability is essential in mathematical problem solving. Meyer (1981) and Akpan (1987) have shown that the ability of secondary school students to compute correlated significantly with their mathematical problem solving performers.

The conclusions discussed above, regarding three related factors apparently contribute to low mathematics. Performance of many students:

a) According to Hackett and Betz (1989) “mathematics teachers should pay as much attention to student self-efficacy as to actual performance” (p. 271). If self-efficacy is an important predictor of performance and is a Primary cause of feelings of self-worth and perceived usefulness, then effort to identify, understand and alter inaccurate judgments should prove beneficial.
b) Lack of knowledge about conceptual and procedural strategies is popular between students. Weakness in the use of strategies also limits students Performance (Mayer, 1985; Forgesen & Kail, 1980).
c) Instruction that focuses on student’s attention to what is the right answer rather than on the process of finding answer on their own. Overall, findings of the current study supported Bandura's theory of self-efficacy and shed light on the identification of potential mechanisms that contribute to differences in mathematics ability of students.

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