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Confirmatory Model of Mathematics Self-Efficacy, Problem Solving Skills and Prior Knowledge on Mathematics Achievement: A Structural Equation Model

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ABSTRACT

The purpose of the current study was to determine the effects of mathematical problem solving skills and prior mathematics knowledge on mathematics achievement and mathematics self-efficacy. Also the effect of mathematics self-efficacy on mathematics achievement was demonstrated. The subjects of the study were middle school students (males and females) of the academic year 2013. 400 of 8th graders were selected from four public schools of Shiraz in Iran. A two stage Cluster Random Sampling Method was utilized. Structural Equation Model was used to analyze the data. The estimate of Structural Equation Model revealed that mathematical problem solving skills and prior mathematics knowledge had a direct and an indirect effect through mathematics self-efficacy on mathematics achievement. The high goodness-of-fit indices that model had a good fit to the given data ($\chi 2{=}2.520 < 5$). Additionally, Confirmatory Factor Analysis was used for validity and reliability of instruments. The results showed the Construct Reliability value for all of subscales were more than .70. Furthermore, the finding of this study indicated the significant relationship between predictor's variables (problem solving skills, prior mathematics knowledge), mathematics self-efficacy as

mediator, and mathematics achievement as criterion variable. The findings supported the hypothesized role of self-efficacy in Bandura's (1986) social cognitive theory and Schoenfeld's (1985) mathematical problem solving theory. This study hopes to accomplish a perfect framework for educators, students, and the Ministry of Education. The obtained results of the current study will bring advantages to the researchers and educators.

Keywords: Mathematics Self-efficacy, Problem Solving Skills, prior knowledge, Structural Equation Model (SEM), Confirmatory Factor Analysis (CFA), Mathematics Achievement.

1. Introduction

As a general subject, Mathematics is required to be learned by any individuals who belong to the society. Nevertheless, the chances to acquire mathematics would determine and restrict their mathematical attainment. Indeed, mathematics is not limited to particular learners while it is known that every student has to know how to think mathematically. While instructing and learning mathematics still remains as daunting undertakings, numerous issues can be observed on the mathematics education at schools.

Studies on cognitive variables such as problem solving, ability, thinking scale, following the findings of Coleman et al. (1966) recommend that the schools do not make a big difference while numerous surveys have been so far executed regarding the in and out-of-school variables that may potentially influence the students' attainment. A voluminous amount of study has explored the association between the learners' individualities like their self-concepts, their attitudes of mathematics, their family backgrounds along with their motivation and consequent academic performance.

After many survey findings, of Education (2010) approved that the student's difficulties with mathematics low performance in secondary school directly related to their motivation, beliefs about mathematics, background in mathematics. Especially in primary and middle school the difficulties related to strategy at problem solving. Whilst mathematics achievement has been the common problems among Iran learners, little attention has been given to learners at the middle school level, which is grade eight. Therefore this study will examine several factors related to mathematics achievement. Unfortunately, students in grade eight did not achieve very high marks in standard exams

such as Math Olympiad in Iran.

The current study is mostly done on the social theory of Bandura and Schoenfeld's model. Social Cognitive Theory (SCT) as the main theory in this study has identified clearly that individuals' knowledge and behaviours such as previous knowledge and beliefs in mathematics predicted individuals' accomplishments such as academic achievements in mathematics through self-efficacy as a mediator. On the other hand, Mathematical Problem Solving Theory (MPST) has recognized obviously that it is necessary to know the skills in mathematics for solving the task. So, in the present study SCT and MPST were used in order to examine the theoretical framework. According to Bandura (1986), individuals possess a self-system that enables them to exercise a measure of control over their thoughts, feelings and actions. Precisely, self-efficacy mediates the effect of other parameters impacting the operation, between which stands the learner on accomplished function. Based on Schoenfeld (1985) success in solving mathematics problems depends on amalgamation of resource knowledge consisting problem solving strategies, monitoring and control, beliefs, effects and practices.

In the general case, as Montague (2006) said, mathematical problem solving as a procedure includes two steps: problem representation and problem execution. Both of them are necessary for successful problem solving. Successful problem solving is not possible without representing the problem appropriately first. Suitable problem representation consists of understanding the problem and guiding the students to the solution plan. On the other hand, problem execution stage includes solving the problem and looking backward. It is so important that the National Council of Teachers of Mathematics (NCTM (2000)) has recognized problem solving skills in mathematics as one of the five fundamental mathematical processes.

In the field of mathematics achievement, several studies used structural equation modeling or path analysis in determining the important variables that effect mathematics performance directly or indirectly via mathematics self- efficacy. Zarch and Kadivar (2006) constructed a structural model on mathematics ability and mathematics performance through mathematics self-efficacy as a mediator. The results indicated that the overall model fit the data reasonably well.

Hailikari et al. (2008) used the structural equation modeling to discover the interaction of prior knowledge, academic self-beliefs, and prior study in mathematics success in predicting the achievement in mathematics. The results indicated that previous study was the strongest predictor of student achieve-

ment through academic self-beliefs and prior knowledge.

During the last decades, the students' little capability in science, especially in mathematics, has turned into a rocketing worldwide concern. According to the recent findings, the academic attainment is accomplished through having an emphasis on learning's individual and social features. The learners' troubles with solving the mathematical tasks and efficient usage of strategies would be directly associated with the students' mathematics beliefs, self-regulation, lack of critical thinking, and problem solving ability (Moscardini (2010); Ismail (2009); Ismail and Awang (2007)).

As a conclusion of Cai and Lester study, recommended that problem solving must not be explained as a discrete subject in mathematics subjects. In point of fact, problem solving should be taught as an integral portion of mathematics curriculum, and it needs a significant warranty in the syllabus at every grade and in every mathematical topic. In addition, focusing on problem solving at every grade level not impacts the expansion pupils' higher-order thinking skills but also amplify positive beliefs. In summary, teachers should focus on developing students' mathematical problem solving skills (Cai and Lester (1906)).

Researchers such as Yusuf (2011) and Ayotolaa and Adedejib (2009) have demonstrated the importance of self-efficacy beliefs for predicting student's achievements in mathematics. For example, self-efficacy predicts mathematics problem solving to have a greater degree than self-beliefs such as mathematics anxiety or self-concept, previous mathematics background, or self-efficacy for self-regulatory exercises.

The result of Babakhani (2011) investigation indicated that self-instruction, a self-regulation strategy, as an element of educational models, is generally effective for mathematics problem solving. A study was done by Ahghar (2012) indicated problem solving skills were effective in self-regulation learning of students and had good stability over time.

The present study was designed to investigate the role of personal variables on students' mathematics achievement. To achieve this goal, three variables, i.e., mathematics self-efficacy, mathematical problem solving skills and prior mathematics knowledge were measured and structural equation modeling analysis was conducted to confirm the related model on the basis of theoretical principles in mathematics education. The specific objectives of the current study was to determine the direct and indirect influence of mathematical problem solving skills and prior mathematics knowledge through mathematics

self-efficacy as the mediator on students' mathematics achievement.

2. Hypotheses

The major hypotheses of this study of grade eight students in Iran include the following:

Hypothesis 1	:	Students' mathematics self-efficacy has a direct influence on their mathematics achievement.
Hypothesis 2	:	Students' problem solving skills has a direct influence on their mathematics achievement.
Hypothesis 3	:	Students' problem solving skills has a direct influence on their mathematics self-efficacy.
Hypothesis 4	:	Students' problem solving skills has indirect effects on their mathematics achievement through their effects on mathematics self-efficacy.
Hypothesis 5	:	Students' mathematics prior knowledge has a direct influence on their mathematics achievement.
Hypothesis 6	:	Students' mathematics prior knowledge has a direct influence on their mathematics self-efficacy.
Hypothesis 7	:	Students' mathematics prior knowledge has indirect effects on their mathematics achievement through their effects on mathematics self-efficacy.

3. Method

3.1 Sample and Data Collection

The data collection was performed in Iran. In the current study, SEM was used to analyze the data. Therefore, the sample size should be adjusted to this technique. According to Kline (2011) SEM analysis needs large sample size. Kline suggests that sample size which is less than 100 is considered small, with between 100 -200 is medium sample size, and with more than 200 is considered large sample size. However, based on Cochran's formula the sample size was estimated 400. The limited of selecting Iranian middle school caused two stage cluster random sampling method was utilized. In this technique (cluster random sampling method) the researcher selected participants from the clusters based on schools (Ary et al. (2010)). It should be noted that the first cluster of the study were based on four educational districts and the second

cluster is based on 45 schools available in the second district. Therefore, the researcher randomly selected the second district among four available districts as the first stage in Shiraz in Iran. Then, four public schools were chosen randomly from 45 schools among the available list of the schools in second district. The sample consisted of 400 (200 male and 200 female) eight-grade students from four schools of Shiraz in Iran.

3.2 Measures

3.2.1 Mathematics Achievement Test

The first construct measured mathematics achievement which consisted of algebra, geometry, arithmetic, and statistics. This standard instrument was adjusted by the Ministry of Education in Shiraz for the entrance exam for grade 9 based on textbook in grade 8. This set of instrument consisted of 22 questions which were used to measure the mathematics achievement construct. Each question was measured on a 5point scale, so the total scores would be 110. Algebra was measured using 6 questions, arithmetic was also measured using 6 questions, and 8 questions measured geometry whilst for statistics 2 questions were given. The purpose of the mathematics instrument was to measure the students' knowledge on the four main subjects based on the 8th grade textbook.

3.2.2 Mathematics Self-efficacy Scale

The second construct in this study was students' mathematics self-efficacy which consisted of mathematics behaviours in everyday life (everyday mathematics tasks) and perceptions of performance capability related to mathematics problems. These sub constructs of mathematics self-efficacy consisted of 22 items that each sub-construct consisted of 11 items which were modified based on Betz and Hackett (2013) Likert scale instrument, middle school textbooks and the expectations from the 8th grade students. These constructs were measured based on the 9 Likert rating scale (rating from 0 as no confidence at all to 9 as complete confidence).

3.2.3 Mathematical Problem Solving Skills Test

The content of mathematical problem solving skills included algebra, geometry, arithmetic, and statistics. This instrument was adjusted by my own self based on strategies which were used in the 8th grade the textbook. The instrument measured 4 skills which were achieved from Polya (2000) steps on

problem solving: understand the problem, make a plan, solve the problem and look back at mathematical problem solving. This set of instrument consisted of 12 questions for each subject. Each question was measured on a 4 point scale with a score of 1 point, so the total score would be 48.

3.2.4 Prior Mathematics Knowledge Score

Students' mathematics scores on the mathematics test administered at the end of the previous academic year (year 2011-2012) were used as the index of students' prior mathematics knowledge. In other words, prior mathematics knowledge was measured by students' previous GPA in mathematics.

3.2.5 Validity of Instruments

CFA is employed for constructing CFA models with three major purposes; to test for model fit, convergent validity, and construct reliability. A CFA was conducted to examine the construct validity of variables items. The analysis was done using Analysis of Moment Structure (AMOS) Software version 22. For the CFA model fit, data were first checked with the model chi-square goodness-of-fit, and approximate fit indices. The CFA models fit were examined based on Chi-square statistics, Goodness-of-Fit Index (GFI), Adjusted Goodness-of-Fit Index (AGFI), Comparative Fit Index (CFI), Incremental Fit Index (IFI), Normed Fit Index (NFI), Tucker Lewis Index (TLI) and Root Mean Square Error of Approximation (RMSEA) indices (set at .05). Convergent validity in the CFA's second step refers to a set of indicators that presume to measure a construct (Kline (2005)). Bentler (1990) suggested the value of CMIN/DF of < 5.0 indicates good fit of the model. Also, Chau (1997), Segars and Grover (1993) suggested that the value of GFI $> .90$ demonstrates good fit of the model. Further, Bentler (1990) declared the value of CFI $> .90$ demonstrates adequate fit of the model. In addition, according to M. and G. (1980), NFI $> .90$ indicated a reasonable fit of the model. Furthermore, Byrne (2010) suggested the RMSEA$< .08$ represent good fit of the model. In this study, the CFA models have indicated acceptable fit to the given data. In other words, all of indices value such as GFI, AGFI, CFI, IFI, NFI and TLI were more than .90. Also, RMSEA index for all of CFA models was less than .08. Above all, chi-square statistic for all CFA models was less than 5 ($p<.05$).

Brown (2006) defines convergent validity as internal consistency of a set of items or indicators. It represents the strength of the relationships between items that are predicted to represent a single latent construct. The characteristics of the items are: 1) They must be strongly related to each other, 2) They

must represent only one factor. The convergent validity can be tested using factor loadings at $\geq .5$ on a factor which would indicate high convergent validity (Hair et al. (2010); Byrne (2010)). However, CFA suggested that each item in the two subscales of students' mathematics self-efficacy including mathematics behaviours used in everyday life or everyday math tasks and the perceptions of performance capability in relationship to mathematics problems had acceptable factor loadings ranging from .54 to .66 on their latent variable. Also, CFA indicated that each item in the four subscales of students' mathematical problem solving skills containing understand the problem, make a plan, solve the problem and look back had passable factor loading ranging from .50 to .65 on their latent variable. Furthermore, CFA inferred that each item in the three subscales of mathematics achievement comprising algebra, arithmetic and geometry had admissible factor loading ranging from .53 to .65. The last subscale of mathematics achievement is statistics. It is not possible to compute the CFA model for this observed variable because it has two items only. According to Hair et al. (2010) number of items could be used to test for the model fit in CFA should be at least 3 items. So, in the present study, it was not possible to conduct the CFA for statistics with only two items. Hence factor loading was computed by using Statistical Package for the Social Sciences (SPSS) version 22. The result showed both of items had acceptable factor loadings (.79) on statistics. These finding showed that the students' mathematics achievement test, mathematical problem solving skills test and mathematics self-efficacy questionnaire were dependable instruments to assess their subscales.

3.2.6 Reliability of Instrument

A reliability analysis by Construct Reliability (CR) for the subscales was conducted by CFA. The CR is comparable to Cronbach's alpha where CR $> .70$ is considered reliable (Hair et. al., 2010). On the other hand, Cronbach's Alpha interpretation such as $\geq .90$ would be considered excellent, $\geq .80$ very good, $\geq .70$ adequate and $< .5$ not reliable (Kline, 2005). The CR was calculated based on a formula given by Fornell et al., (1981). The CR formula was calculated as follows:

$$CR = \frac{(\sum \lambda)^2}{(\sum \lambda)^2 + (\sum \delta)}$$

Where, λ Factor loading () and δ measurement error. In the current study, CR was calculated manually to measure construct reliability.

However, the CR value for all of subscales were more than .70 such as algebra (CR=.93), arithmetic (CR=.86), geometry (CR=.91), understand the problem (CR=.92), make a plan (CR=.92), solve the problem (CR=.92), look back (CR=.92), perceptions of performance capability related to mathematics

problems (CR=.80) and mathematics behaviors in everyday life (CR=.70). On the other hand, as mentioned above, it was not possible to conduct the CFA for statistics with only two items so, Cronbach's alpha by using SPSS indicated high internal consistency for the students' achievement on statistics(α=.83, .84). These results suggested the scales had high internal consistency and reliability.

4. Results

Assessment of structural Model

As shown in Figure 1, the hypothesis was to analyses the full structural model that investigated the relationship among the predictor variables, the mediator and the criterion variable.

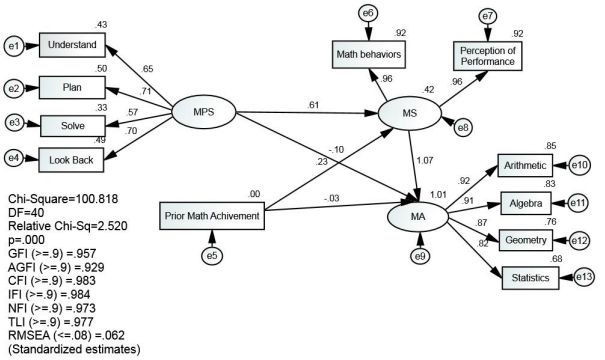

Figure 1: Completely standardized parameter estimates for the structural equation model of mathematics achievement
Note: MS(Mathematics Self-efficacy), MA(Mathematics Achievement),
MPS(Mathematical Problem Solving), and PMA(Prior Mathematics Knowledge)

The model provided a good fit to the given data $\chi 2$ [40df, N=400] =2.520, p=.000, CFI=.98, TLI=.98, GFI=.96, AGFI=.93, IFI=.98, NFI=.97, and RMSEA=.06.

Results presented in table 1 (Regression Weights) indicated that there are significant relationships between predictor variables and mathematics self-efficacy as a mediator such as mathematical problem solving skills (β=.61,p = .000 < .001) and prior mathematics knowledge (β=.23,p = .000 < .001). Also, students' mathematics self-efficacy had a very high and significant ef-

Table 1: Regression Weights and Standardized Regression Weights.

Path		Unstandardized Estimate	S.E.	C.R.	P	Standardized Estimate
MS	<— PSS	9.825	1.015	9.683	***	.610
MS	<— PK	2.267	.423	5.361	***	.226
MA	<— MS	.076	.003	23.796	***	1.069
MA	<— PK	-.021	.012	-1.655	.098	-.029
MA	<— MPS	-.117	.032	-3.641	***	-.102
UP	<— MPS	1.000				.654
MP	<— MPS	1.121	.104	10.765	***	.708
SP	<— MPS	1.061	.115	9.223	***	.571
LB	<— MPS	1.124	.105	10.700	***	.701
Alg	<— MA	3.227	.136	23.756	***	.909
Arith	<— MA	3.297	.135	24.419	***	.924
Geo	<— MA	2.686	.121	22.127	***	.872
MB	<— MS	1.000	.121			.960
POP	<— MS	.337	.007	46.631	***	.960

*p<.001

Note: MS(Math Self-efficacy), PSS(Problem Solving Skills), MA(Math Achievement), Geo(Geometry), Arith(Arithmetic), Alg(Algebra), Stat(Statistics), MB(Mathematics Behaviours in everyday life), UP(Undrestand the Problem), POP(Perceptions of Performance capability related to Mathematics problems), MP(Make a Plan), SP(Solve the Problem), LB(Look Back), PK(Prior Knowledge)

fect on their mathematics achievement (β=1.07,p = .000 < .001). On the other hand, there was negative and insignificant relationship between students' prior mathematics knowledge and their mathematics achievement (β=-.03,p = .098 > .001). In addition, the relationship between students' mathematical problem solving skills and their mathematics achievement was negative and significant (β=-.10,p = .000 < .001). According to Kline (2005) , the occurrence of obtaining coefficients with different signs in the result of a suppression criterion while controlling for other predictors is a "surprise" given the correlation between that predictor and the criterion (Kline (2005)).

5. Discussion and Conclusion

The findings of this study by providing evidence on the relationship between psychological and mathematical variables and mathematics achievement

based on social cognitive theory and mathematical problem solving theory contribute to students' achievement in mathematics as well as contribute to the expand of the correlation general. In fact, this study explored the amount and percentage relationship between psychological and mathematical variables such as students' prior mathematics knowledge and mathematical problem solving skills on students' mathematics achievement among Iranian middle students.

The statistical results indicated that students' problem solving skills in mathematics is an important variable to explain students' performance in mathematics. In other words, based on MPST the students who applied the skills such as understand the problem, make a plan, solve the problem, and look back to solve the mathematics problems had better performance in mathematics on algebra, arithmetic, geometry, and statistics. Also, the research results showed that students' problem solving skills in mathematics also play a valuable role in simplifying components such as mathematics behaviours used in everyday life and perception of performance capability in relationship to mathematics problem of students' self-efficacy in mathematics. In other words, the students who know the skills of mathematics problems solving had high self-efficacy in mathematics. In other words, the finding of this study indicated that students' problem solving skills in mathematics directly and indirectly influence their mathematics achievement; In other words, the present study revealed that students' mathematical problem solving skills had a direct negative and significant effect on mathematics achievement and also an indirect positive effect between students' mathematical problem solving skills and their mathematics achievement through students' mathematics self-efficacy was focused.

The study findings demonstrated that students' prior achievement in mathematic is an important variable to explain students' performance in mathematics. In other words, the students who previously had better performances in mathematics, had better achievement in mathematics on mathematics subjects such as algebra, arithmetic, geometry, and statistics. The results demonstrated that students' prior achievement in mathematic also play an important role in facilitating the components such as mathematics behaviours used in everyday life and perception of performance capability in relationship to mathematics problem of students' self-efficacy in mathematics. In other words, the students who formerly had better achievement in mathematics also had high self-efficacy in mathematics. The current study revealed that students' prior mathematics achievement had a direct negative and no significant effect on mathematics achievement and also an indirect positive effect between students' prior mathematics achievement and their mathematics achievement through students' mathematics self-efficacy was emphasized.

The findings indicated that students' mathematics self-efficacy appeared to be the most influential mediating variable in explaining students' achievement in mathematics that supported Bandura's SCT. In other words, the components of students' mathematics self-efficacy; mathematics behaviours used in everyday life and perception of performance capability in relationship to mathematics problem; have important role in explaining students' achievement in mathematics by predictors such as students' mathematical problem solving skills, and prior mathematics achievement.

These finding showed, students' mathematical problem solving skills and prior mathematics knowledge predicted mathematics achievement through its influences on mathematics self-efficacy. These finding supported the assumption that mathematics self-efficacy might facilitate students' achievement in mathematics. Precisely, the above findings were similar to the existing literature on self-efficacy, prior mathematics knowledge, and mathematical problem solving skills in relation to the students' academic achievement in mathematics (Hailikari et al. (2008); Kiamanesh and Mahdavi-Hezaveh (2008); Kabiri and Kiamanesh (2004); Schunk and Meece (2005); Liu and Koirala (2009)).

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