A Comparison Between Ordinary Least Square (OLS) And Structural Equation Modeling (SEM) Methods In Estimating The Influencial Factors Of 8th Grades Student's Mathematics Achievement In Malaysia

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Abstract – This research demonstrates the application of Structural Equation Modeling (SEM) method in order to obtain the best fit model for a more efficient and accurate inter-relationship among variables findings and interpretation. For the purpose of this study, secondary data of Trends in International Mathematics and Science Study (TIMSS) had been used. The data were distributed by using two stage stratified cluster sampling technique and involving 5733 eighth grades students in Malaysia. A Confirmatory Factor Analysis (CFA), Discriminant Validity and Path Analysis had been conducted to obtain the best fit model of SEM. At the end of the study, the best fit model was then compared to the Ordinary Least Square (OLS) model method. From the Chi-Square value, it is found that the model of SEM method is much better compared to OLS model method based on its fitness and accuracy.

Keywords- Mathematics Achievement, Mediation, Ordinary Least Square, Structural Equation Modeling, TIMSS

1 INTRODUCTION

Structural Equation Modeling or also known as SEM has gained popularity among researchers, academicians and students nowadays. It is due to its flexibility and generality besides can generate an accurate and precise estimation in making prediction. SEM analysis goes through the steps of model specification, data collection, model estimation, model evaluation and also model modification. SEM is a unique method because the researcher can modify the structural model in order to increase the model fitness.

Ordinary Least Square or also known as OLS is one of the method used in making prediction and estimation. Same as SEM, it is used to analyze the relationships among (independent, dependent and mediator) variables. Researchers usually use OLS in Regression Analysis and Correlation Analysis in which also can be performed using SEM.

However, problems exist during data analysis by using OLS is when multiple response items are used in measuring the variables. What researchers, academician or students normally do in Ordinary Least Square (OLS) method with this problem is by computing the mean response of these items to measure the variables which is theoretically inefficient and will lead to inaccurate findings later on. SEM is said to be better than OLS because it has the ability to calculate the affect of items under each variables individually besides it takes into consideration the structure of mean, variance and covariance simultaneously in its analysis for a more efficient and accurate findings.

A secondary data obtained from Trends in Mathematics and Science Study (TIMSS) will be used to run both SEM and OLS methods to compare their fitness in order to prove the theory whether it is acceptable or not. Based on the findings, a better method will be identified for the use of other researcher in obtaining a more accurate and precise result in their research.

2 MATERIALS

The population of the study is defined as the eighth grades (form two) students in Malaysia. Our target population is eighth grades students in Malaysia. A value of 5733 respondents was randomly chosen from 180 randomly chosen schools in Malaysia. In this case study, eighth grades student's attitude towards Mathematics acts as mediating variable and achievement in Mathematics examination acts as dependent variable for this study.

Data were obtained from the Trends in International Mathematics and Science Study (TIMSS) international database. Respondents were normally selected through a two stage stratified cluster sampling technique in which consist of cluster sampling for the first stage, school sampling for the second stage and class sampling for the third stage. The questionnaire consists of four independent variables which are; school environment, teacher's characteristics, student's self-confidence in Mathematics and Student's motivation in Mathematics. It also contain

student's attitude in Mathematics which acts as mediating variable and student's Mathematics achievement as the dependent variable. The data mining software SPSS PASW version 18.0 and SPSS AMOS were used for the purpose of building model. Several analysis used in this study are Confirmatory Factor Analysis (CFA), Discriminant Validity, Path Analysis, Structural Equation Modeling (SEM) and Chi Square test.

3 METHODS

3.1 Confirmatory Factor Analysis

Confirmatory Factor Analysis (CFA) is a special form of factor analysis, most commonly used in social research. It is the extended analysis of Exploratory Factor Analysis (EFA) and used to test whether measures of a construct consistent with a researcher's understanding of the nature of that construct (or factor). As such, the objective of confirmatory factor analysis is to test whether the data fit a hypothesized measurement model. Model fit measures could then be obtained to assess how well the proposed model captured the covariance between all the items or measures in the model. All redundant items exist in a latent construct will be either removed or constrained. Model fitness estimation are as follows:

Name of Category	Level of Acceptance	Literature
Factor Loading	Weight > 0.5	Heir et al (2006)
Absolute Fit	P > 0.05	Wheaton et al. (1977)
	RMSEA < 0.08	Browne and Cudeck (1993)
	GFI > 0.9	Joreskog and Sorbom (1984)
Incremental Fit	AGFI > 0.9	Tanaka and Huba (1985)
	CFI > 0.9	Bentler (1990)
	TLI > 0.9	Bentler and Bonett (1980)
	NFI > 0.9	Bollen (1989)
Parsimonious Fit	Chisq/df < 5.0	Marsh and Hocevar (1985)

3.2 Discriminant Validity

Discriminant validity is the degree to which scores on a test do not correlate with scores from other tests that are not designed to assess the same construct. Correlation coefficients between measures of a construct and measures of conceptually different constructs are usually given as evidence of discriminant validity. If the correlation coefficient is high (>0.85), then the discriminant validity is considered as weak, depending on the theoretical relationship and the magnitude of the coefficient. On the other hand, if the correlations are low to moderate, this demonstrates that the measure has discriminant validity.

$$\text{Correlation coefficient} = \frac{r_{xy}}{\sqrt{r_{xx} \cdot r_{yy}}}$$

where:

r_{xy} = correlation between x and y

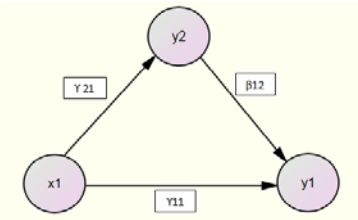
r_{xx} = reliability of x

r_{yy} = reliability of y

3.3 Path Analysis

Path Analysis can test the significance of mediator variable in linking independent variables to dependent variable or simply called as mediation test. It can determine the existence of direct and indirect effect of independent variable towards dependent variable. Usually in SPSS/ANOVA, the conventional regression needs to be analyzed separately in order to determine the mediating effect. However in AMOS, the regression equations can be run simultaneously in one diagram. There are three types of mediation which are:

a) Complete mediation: Occur when the independent variable links towards the dependent variable only through mediator variable and there is no direct effect of independent variable towards dependent variable.
b) Partial mediation: Occur when independent variable links towards the dependent variable through mediator variable and there is also a direct effect of independent variable towards dependent variable.
c) No mediation: Occur when independent variable does not link to the dependent variable through mediator variable but has a direct effect towards dependent variable.



The diagram above shows the example of mediation test. X1 acts as independent variable, y2 acts as mediator variable and y1 acts as dependent variable. In mediation test, the direct/indirect effect of x1 towards y1 can be determined.

3.4 Structural Equation Modeling (SEM)

The Structural Equation Modeling or popular known as SEM is a second generation statistical analysis techniques developed for analyzing the inter-relationships among

multiple variables in a model. The relationships among variables could be expressed in a series of single and multiple regression equations. SEM technique employs the combination of quantitative and the correlational or causal assumptions into the model (Zainudin, 2012). SEM can indirectly estimates the items under latent construct individually. Latent construct is the variable which can't be measure directly since it is only a hypothetical concept of a research. Latent construct is also known as unobserved variables, it is measured using a set of items in a questionnaire. The use of SEM is also able to model the relationship among these constructs and analyze them simultaneously.

4 RESULTS AND DISCUSSIONS

4.1 Structural Equation Modeling (SEM)

TABLE 1
THE LATENT CONSTRUCTS SUMMARY TABLE

Construct	Item	Factor Loading	Cronbach Alpha	CR	AVE
School	sch1	.679	0.712	0.714	0.674
	sch2	.654			
	sch3	.689			
Teacher	tea1	.570	0.792	0.795	0.699
	tea3	.704			
	tea4	.802			
	tea5	.722			
Confidence	sc1	.727	0.710	0.770	0.726
	sc4	.711			
	sc6	.740			
Motivation	mot1	.491	0.767	0.775	0.633
	mot3	.823			
	mot4	.762			
	mot5	.566			
	mot6	.523			
Attitude	att1	.852	0.826	0.841	0.746
	att3	.529			
	att4	.696			
	att5	.908			
Achievement	ach01	.861	0.990	0.940	0.892
	ach02	.936			
	ach03	.900			
	ach04	.873			

Table 1 above shows the Factor Loading (standardized regression weight), Cronbach Alpha, Critical Ratio (CR) and Average Variance Extracted (AVE) values of last latent construct variables. According to Zainudin (2012), the factor loading for a newly developed scale must be higher or equal to 0.5. In this study, all items with factor loading value of lower than 0.5 were dropped from its' constructs to ensure the unidimensionality, parsimonious, incremental and absolute fits can be achieved. Item mot1 of motivation construct however is being kept in the model since the item initially has a factor loading of higher than 0.5. Pooled CFA was also applied since a few constructs have less than four items in its' construct which will lead to identification problem. In this study, after all items of less than 0.5 were decided to be removed or kept in each latent construct, the Modification Indices (MI) of items under each latent construct was checked. If the MI value of a pair of items are greater than 15, the items need to be set as 'free parameter estimate' or constrained because they are considered to have high correlation in which would jeopardize the model fitness. In this study, items (ach01 and ach04, mot1 and mot5, mot1 and mot6, mot3 and mot5) have MI value of greater than 15, they are then be constrained by a double headed arrow. Also through MI value, items att2, sc3 and mot2 were removed because they are extremely correlated with items att3, sc5 and mot1 with MI values of 753.8, 566.156 and 252.866 respectively.

As for measurement values, all constructs have achieved the minimum estimation required which are 0.70 for Cronbach Alpha, 0.60 for CR and 0.50 for AVE. Therefore, it can be concluded that Convergent Validity (AVE ≥ 0.5), Internal Reliability (Cronbach Alpha ≥ 0.6) and Construct Reliability (CR ≥ 0.60) of all constructs had been achieved.

TABLE 2
THE LATENT CONSTRUCTS FITNESS SUMMARY TABLE

Construct	Parsimonious	Incremental		Absolute		
	Chisq/ Df	TLI	CFI	AGFI	GFI	RMSEA
School	4.273	.993	.998	.996	.999	.025
Attitude	3.966	.993	.998	.989	.998	.046
Confidence	3.277	.997	.999	.997	.999	.021
Motivation	2.956	.997	.999	.997	1.00	.020
Teacher	4.904	.995	.998	.994	.999	.031
Achievement	3.156	.988	.998	.962	.996	.046

Table 2 above shows the fitness indices of all latent constructs in the model. All constructs have a ChiSq/df value of less than 5.0, therefore the Parsimonious fit had been achieved. Constructs also have TLI, CFI, AGFI and GFI values of higher than 0.9 and RMSEA value of less than 0.05. Therefore, Incremental and Absolute fitness also had been achieved. It can be concluded that all fitness required in modeling had been achieved.

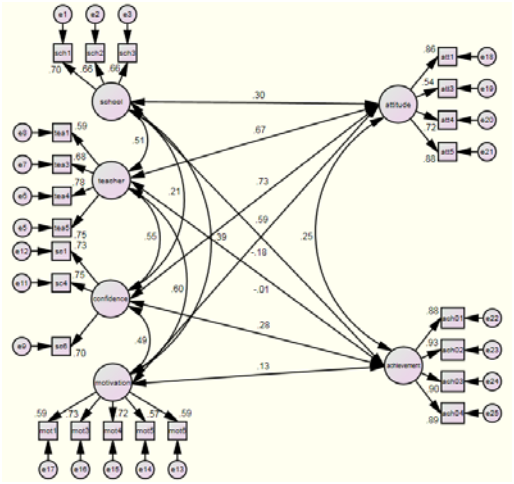


Fig.1 The Standardized Regression Weight

TABLE 3
DISCRIMINANT VALIDITY INDEX SUMMARY

Constructs	Constructs	Correlation
School	School	.75
	Teacher	.51
	Confidence	.21
	Motivation	.39
	Attitude	.30
	Achievement	-.18
Teacher	Teacher	.84
	Confidence	.55
	Motivation	.60
	Attitude	.67
	Achievement	-.01
Confidence	Confidence	.79
	Motivation	.49
	Attitude	.73
	Achievement	.28
Motivation	Motivation	.80
	Attitude	-.18
	Achievement	.13
Attitude	Attitude	.86
	Achievement	.25
Achievement	Achievement	.94

Fig.A and Table 3 shows the strength of correlation between all constructs in the model. All constructs have correlations of less than 0.85. It can be concluded that discriminant validity had been achieved and no construct need to be dropped from the model.

TABLE 4
UNSTANDARDIZED REGRESSION WEIGHT OF MODEL

			Estimate	S.E.	C.R.	P
attitude	<-	teacher	.333	.021	16.119	***
attitude	<-	motivation	.301	.031	9.779	***
attitude	<-	confidence	.542	.022	25.074	***
attitude	<-	school	-.031	.022	-1.390	.165
achievement	<-	school	-.181	.019	-9.714	***
achievement	<-	teacher	-.176	.018	-9.793	***
achievement	<-	confidence	.167	.020	8.297	***
achievement	<-	motivation	.098	.025	3.915	***
achievement	<-	attitude	.183	.019	9.652	***

The table 4 above shows the value of regression weight for the independent latent constructs toward attitude (mediating) and achievement (dependent) variables. All independent latent constructs have significant effect towards both attitude and achievement variables thus have partial mediation role in linking to achievement except for school variable which is not significantly link to attitude. Therefore, school variable has no mediation in linking with achievement.

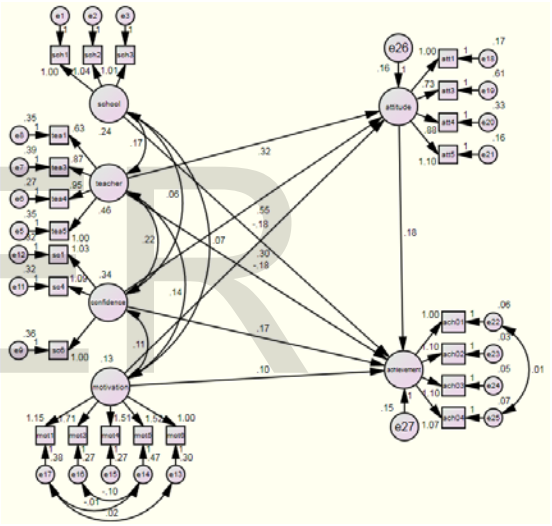


Fig.2 Final constructs model

TABLE 5
MODEL FITNESS

Model	CMIN	DF	CMIN/DF	RMSEA
Default model	944.218	257	3.674	0.050

The ChiSquare/df and RMSEA value indicate that the model has achieve a good fit model since the ChiSquare/df value is 3.674 which is less than 5.0 and RMSEA value is 0.05 which is less than 0.08.

4.2 Ordinary Least Square (OLS)

In OLS, the mean response of each constructs were first computed before proceed to the analysis.

For each of the following paths, the significance of independent variable(s) towards its' corresponding

dependent variable were determined by using multiple linear regression. From the analysis, insignificant variable(s) in each path will be dropped from the model.

Path 1: Attitude = β0 + confidence (x1) + motivation (x2) + teacher (x3) + school (x4) + ε
Path 2: Achievement = β0 + confidence (x1) + motivation (x2) + teacher (x3) + school (x4) + ε
Path 3: Achievement = β0 + Attitude (x1) + ε

In model 1, all independent variables have a significant contribution towards mediator. However, school has been excluded from the model because the significance contribution towards the attitude (mediator) is too low. In model 2, all independent variables have a significant contribution towards dependent variable and no variable had been excluded from the model. There is also no excluded variable in model 3 since attitude has a significance and high contribution towards student's achievement.

From the result of the multiple linear regression, the last model obtained was then implemented into SEM model and the model fitness indexes were generated as fig.C below.

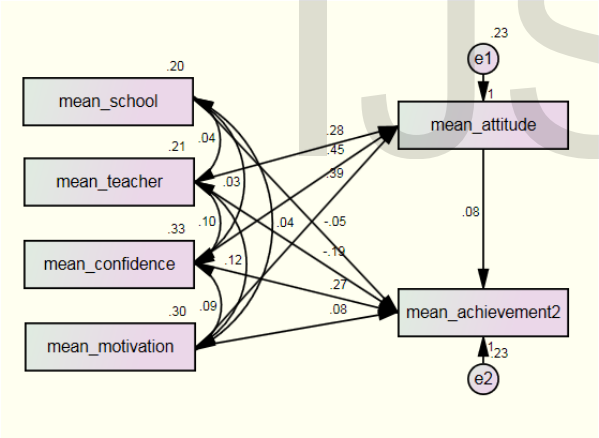


Fig.3 Implemented OLS model

TABLE 9
MODEL FITNESS

Model	CMIN	DF	CMIN/DF	RMSEA
Default model	59.985	1	59.985	0.107

The ChiSquare/df and RMSEA value indicate that the model not achieve a good fit model since the ChiSquare/df value is 59.985 which is higher than 5.0 and RMSEA value is 0.107 which is higher than 0.08.

5 Conclusion.

From the analysis that had been conducted for both methods, SEM method has a better result because the model fitness was achieved through this method. The model fitness was estimated by using ChiSquare/df and RMSEA value. SEM model achieved fitness for both estimation used which are ChiSquare/df value of less than 5.0 and RMSEA value of less than 0.08. However, OLS model doesn't achieve the model fitness since both its' ChiSquare/df and RMSEA value are greater than the acceptance level. Therefore, it can be conclude that SEM method is much more accurate and efficient in order to make estimation for multiple items variable (latent construct). However, it doesn't mean that OLS method is not good in making estimation. For a single item variable, it is better to use OLS method compared to SEM because one of the disadvantage of SEM is its' long and complicated processes in order to achieve a good fit model. Methods have their own disadvantages, even SEM is more accurate and precise, other disadvantage of SEM is items may have to be dropped from the model in order to achieve unidimensionality. If not, it is impossible to achieve model fitness. Besides that, items under a construct must at least consist of four items to avoid' identification problem' where fitness indexes value are unable to be generated. For a better result, pooled CFA method can be used so that unidimensionality can be achieved even items under a construct is less than four.

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