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Application of Structural Equation Modelling in Estimating the Contributing Factors to Mathematics Performance

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ABSTRACT

This research shows the application of the Structured Equation Modelling (SEM) to obtain the best model for studying the relationship between the more efficient and accurate against the findings and the interpretation of the variables. The main objective of the study is in parcel admonished to enlighten reliability model that contains relationships between variables, science and mathematics attitude toward Malaysian student's achievement to test validity construct of the research. Validity and reliability of the measurement model in the analysis using Structural Equation Modelling (SEM) method. Based on the results obtained, all indices meet standardized metric and assessment tools have proven to be a good instrument. The results show that there are three factors that influence student's mathematics performance with the different type of attitude. Analysis found that the integration of belief, effort and self-efficacy factors constitute a strong association to estimate a complete structured equation model while supported by demographic factors such as gender and parents education level.

Keywords: Structural Equation Modelling, Attitude toward Mathematics, Goodness of Fit Index, Validity and Reliability

1.0 INTRODUCTION

Research in Mathematics education in Malaysia is arguably growing with the advancement and change of times. Various parties have begun to realize their role and the importance of mathematics in realizing the dream of a nation industrial development in the future. Math is a driving force to the development of science and technology. Therefore, mastery of knowledge Mathematics needs to be improved over time to produce a workforce in line with the improvement and need to form a developed nation. However, most of the students, whether they are primary school students, secondary or university levels are not interested in Math subjects (Oktiningrum, W., Zulkardi, Z., & Hartono, Y., 2016). Math is often viewed as an unattractive, difficult and scary subject including negative perceptions (Hall, J., & Suurtamm, C., 2018). In the education system in Malaysia, Math is considered as a compulsory subject. The fundamentals of Mathematics need to be placed as one in formal education to all students. Malaysia is already lagging behind in the program International Science and Mathematics assessments such as Program for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS). Achievements Malaysia in the 2015 PISA among 39 countries, ranked 22nd in Mathematics and 24th in Science (TIMSS, 2015).

2.0 LITERATURE REVIEW

Math is a subject that must be learned in school and is a compulsory almost all majors in institutions of higher learning (Kharuddin, A. F., & Ismail, N. A., 2017). In education, math is one of the subjects that the authorities are very concerned. Educational mathematics requires a strong curriculum, up-to-date pedagogy, and level of students, teachers who are knowledgeable and have a high commitment to achieve excellence. Since childhood we have been exposed to various mathematical concepts. These include additions, subtractions, multiplications, ratios and more. The most important medium in mathematical information dissemination is in school. At school students are exposed to how to solve math problems from simple to more difficult levels.

Therefore, the teaching method used by educators is very important for the students understand the concept of math itself. Educators use a variety of methods to provide understanding of students during the teaching and learning process. Teaching effective will have a great impact on learning. Math is also an important subject and also one of the challenging subjects for most students (Kharuddin, A. F., Kamaruddin, S. A., Kamari, M. N., Mustafa, Z., & Azid, N., 2018). Teachers need to strive for create a learning environment that engages students because they are students requires a strong foundation in the development of mathematical concepts to develop and apply their knowledge effectively. Students should also be given the opportunity to improve their skills in investigating, solving problems and communicating or interact while solving problems in mathematics. Planned activities should enable students to see the continuity between the mathematical concepts as well as giving them an opportunity to draw on what they learned with real life.

Quality of mathematical education since the beginning of the educational process has been an essential (Mohd. Yusof, 2012). Refer to Figure 1, learning mathematics is about process of exploring, applying and culturing the mathematics (May & Stone 2010). According to Nik Azis (2009), studies at the individual level such as value development by students can give an overview of their value and role it in mathematics education. The current scenario lacks meaningful experience in the context of everyday life (Lim 2012; Bishop et al. 2001) for mathematics subjects is not help students become a good math practitioners. Students should not just be gaining mathematical

knowledge, but can be taught the beauty of math's values indirectly.

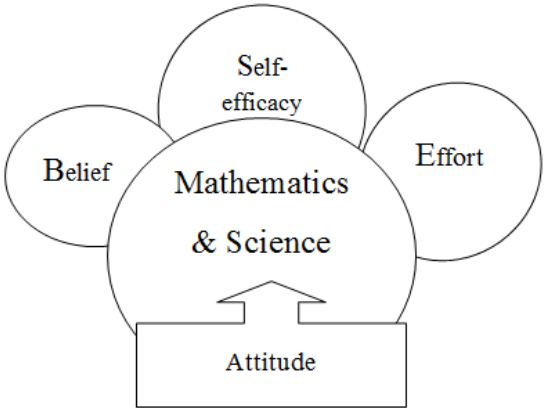

Figure 1: Domain of the Mathematics Attitude Scale

In an earlier International Commission on *Mathematical* Instruction (ICMI) Study 'Gender and Mathematics Education' it was reported that the use of technology in mathematics might erode the advances made toward gender equity in mathematics (Hanna and Nyhof-Young, 1995). Just a couple of individuals have researched gender orientation issues as for the utilization of innovation in science. With regards to a narrowing hole in gender orientation contrasts in student execution (William *et al.*, 1992), they found no proof to help the speculation that noteworthy and predictable sex contrasts influence student's performance. The examination concentrated on homeroom practices and culture in mathematics and science as past investigations had indicated the connection between study hall rehearses and separated learning results (Fennema, 1995). However, Sacerdote (2001) found that grades are higher when students have unusually academically strong roommates and grouped with other good student in mathematics class session (ZajoNc, 1976).

Kouba & Mc Donald (1987) belief influence on student performance does change as students grow older. Scholastic integration, in some cases been utilized to portray a bunch of scholarly factors that can impact maintenance and has been characterized as "the improvement of a solid connection with the school condition both inside and outside of class (Nora, 1993). Students can and should learn at higher levels, but it should not be considered as constraint because there are other factors like race and gender can affect student's performance. Student performance is affected by different factors such as learning abilities because of a new paradigm in teaching and learning (Hansen & Joe B, 2000).

3.0 SAMPLING METHOD

Structural equation modeling (SEM) is a prevailing, multivariate technique found increasingly in scientific investigations to experiment and assess multivariate causal associations (Briere, J., Runtz, M., Eadie, E., Bigras, N., & Godbout, N., 2017). The popularity of this approach is increasing among researchers, academics and students. This is due to the flexibility and coverage in producing accurate and fast estimates in making predictions (Jacobucci, R., Grimm, K. J., & McArdle, J. J., 2017)). Steps in the SEM analysis follow model specifications, data collection, budgeting, interpretation and modification of the model (Godbout, N., Daspe, M. È., Runtz, M., Cyr, G., & Briere, J., 2019). However, the validity of this index value must be obtained to assure the acceptance and rejection of the model (Garn, A. C., & Webster, E. K., 2018). This accomplishment is used in the assessment to hypothesize the factors that affecting math performance among Malaysian students. The data obtained from this investigation estimates the major contributing factor to student's performance in math perspectives.

Samples of 9726 form two students from various schools were taken to fit the model in this study. The respondents of the survey were individuals who attended TIMSS survey directly. Identified mediating variables are including the belief, self-efficacy and effort. All of these determinants are assessed to be the level of math attitude through form two students' perspectives. These different

perspectives act as mediating variables that are keys of success to this study. The data were obtained from a survey conducted through a questionnaire that has been verified for its reliability. IBM SPSS® AMOS® v23.0 software has been used for model fitting and analysis purposes. The analysis used in this study was Confirmatory Factor Analysis (CFA), Discriminant Validity (DV), Path Analysis (PA) and Structured Equation Modeling (SEM). The first step is to carry out the Confirmatory Factor Analysis (CFA) that is commonly used in social investigations. It is an advanced analysis of the Exploratory Factor Analysis (EFA) and is used to test whether the steps are in line with the research objective or need to be justified. Therefore, the objective of the CFA is to rectify the data corresponds to the hypothesized measurement model. Model fit measures are then obtained to assess the extent to which the proposed model has a covariance that links all items in the model.

4.0 DATA ANALYSIS

The goodness-of-fit index was verified by χ^2 values (degree of freedom or df, p-value), weighted root mean square residuals (WRMR; reference value: ≤ 1.0), the Tucker-Lewis index (TLI; reference value: ≥ 0.9), the comparative fit index (CFI; reference value: ≥ 0.9), and the root mean square error of approximation (RMSEA; reference value: ≤ 0.05). The convergent validity of the factor construct was based on the following criteria: standardized regression coefficients of observed variables ≥ 0.50, construct reliability (CR) ≥ 0.7, and average variance extracted (AVE) ≥ 0.5. The discriminant validity of the factors estimated by CFA is confirmed if the inter-factor correlation coefficients are ≤ 0.80 and the AVE of latent variables is greater than the square of correlation coefficients of the latent variables. To assess the criterion validity of the attitude towards mathmatics, a standard scale with proven validity and reliability was essential. However, because there are very few instruments designed to measure students' attitude conceding and almost none have proven validity and reliability, the findings from this study were compared to a previous study (Rentzou, K., 2017) on the math performance. Hence, the Pearson's correlation coefficient between the performance and mediators were obtained for criterion validity. To enumerate internal consistency, Cronbach's alpha correlation coefficient was obtained.

Several techniques were used to assess the reliability coefficient, Cronbach alpha, α (1951), and to assess convergence validity. Confirmatory factor analysis (CFA) is the method for measuring latent variables (Hoyle 1995; 2011; Kline 2010; Byrne 2013). It excerpts the latent construct from other variables and recompenses the most variance with related variables. For example, mathematical belief as a latent variable is measured by the observation of understanding (i.e., confortable, ability, creative thinking and jobs needed, (Berti, S., Cigala, A., & Sharmahd, N., 2019). Confirmatory factor analysis evaluates latent variables based on the associated variations of the dataset (e.g., association, causal association) and can reduce the data dimensions, standardize the scale of multiple indicators, and account for the associations' integral in the dataset (Byrne 2013). Therefore, to hypothesize a latent variable, one should be distressed about the reason to use a latent variable. In the belief factor example given above, ability and creative thinking are latent variables that account for the association in the dataset. Shao et al. (2015) applied CFA to compress the jobs needed features to one variable that accounted for math understanding. Also, Capmouteres and Anand (2016) defined the Confirmatory factor analysis (CFA) is a tool that is used to approve or discard the measurement theory. In addition to CFA, there is another type of factor analysis: exploratory factor analysis (EFA). The statistical estimation technique is the same for both. The CFA is applied when the indicators for each latent variable is specified according to the related theories or prior knowledge (Austin, P. C., Lee, D. S., & Leckie, G., 2020), whereas EFA is

applied to find the fundamental latent variables. In practice, EFA is often performed to select the useful underlying latent constructs for CFA when there is little prior knowledge about the latent construct (Hajizadeh, A. & Zali, M. (2016). Confirmatory factor analysis (CFA) was used to quantify the items' construct validity in each sub construct that measure math attitude instrument. The first step in this measurement model is to determine the convergent validity and discriminant validity. Table 1 shows the result of CFA for measurement model, the factor loading of more than 0.70, Average variance extracted (AVE) more than 0.50 and Composite reliability (CR) more than 0.70, thus this math attitude instrument has good convergent validity and adequate reliability.

Table 1: Result of CFA for measurement model

Construct	Item	factor loading	Composite reliability (>0.7)	Average variance extracted (>0.5)
Demographic	BSBG11	0.761	0.381705	0.145699
	BSBG07B	-0.007		
	BSBG07A	-0.012		
	Gender	-0.059		
EFFORT	MLRC	0.64	0.753327	0.567502
	MLRF	-0.689		
	MLRA	-0.84		
	MLRD	-0.698		
	MLRE	-0.872		
SELFEFFICACY	MLSF	0.807	0.731871	0.535635
	MLSB	0.765		
	MLSG	0.595		
	MLSD	0.699		
	MLSE	0.774		
BELIEF	MBC	0.81	0.717869	0.515335
	MBB	0.675		
	MBE	0.659		
Performance	SSCORE	0.803	0.935257	0.874705
	MSCORE	1.051		

4.1 Discriminant validity

There are several types of validity measures that include face validity and construct validity. Mohajan, H. K. (2017) proposed two types of validity: convergent and discriminating validity. Convergent validity is measured by average variance extracted for each construct during the reliability analysis that should be 0.5 or 50% or better. Table 1 show the reliability values for the various construct with variance extracted in diagonal format given in bold. Cronbach alpha for the construct range from 0.72 to 0.75 indicating a sufficient level of reliability and convergent validity of all constructs. In general, results show in Table 2 that both validities are satisfied.

Table 2: Pearson Correlations and AVE Table for Discriminant Validity

	No of original scale items	Alpha	1	2	3
Effort (1)	5	0.753	**0.75**		
Efficacy (2)	5	0.731	0.65	**0.73**	
Belief (3)	3	0.717	0.51	0.21	**0.72**

4.2 Measurement model

Research in social sciences has been used statistical analysis for over a century. The decision-making through statistical methods has grown dramatically with the help of computer capabilities. The use of technology and user-friendly is one of the main reasons why access to statistical analysis has been widely practiced over recent years. In understanding data relationships, researchers must rely on univariate and bivariate analysis through an advanced multivariate data analysis methods such as Structural Equation Modelling. Structural Equation ModeLling or SEM is also a second generation statistical analysis technique developed for analysing the association between multiple variables within a model framework. SEM techniques use quantitative combinations and correlation or causal assumptions into the model (Zainudin, 2012; Shipley, B., 2016; Lachowicz, M. J., Preacher, K. J., & Kelley, K., 2018; Ning, B., Ghosal, S., & Thomas, J., 2019). SEM also can indirectly evaluate items under the latent construction individually. The latent construct is a variable that cannot be measured directly because it is just a concept of research hypothesized. Latent constructs are also known as variables that cannot be directly assessed or measured using a set of items in the questionnaire. The use of SEM can also model an association between constructions and simultaneously analysed.

5.0 RESULTS

The study population included 4711 males (48.4%) and 5015 females (51.6%), with a mean age of 14 ± 0.60 years. Almost all items (16/19) showed an item-level content validity index ranging between 0.70 and 1.00 and the scale-level content validity index/AVE of 0.70, indicating adequate content validity. We analysed the skewness and kurtosis to discover the normality of the data used in this study. The skewness of all measured variables was between 0.01–1.15 (absolute value) and did not exceed 3; kurtosis did not exceed 10 and had absolute values between 0.04–1.41. The data presented normal distribution. However, the multivariate normality test showed that the multivariate kurtosis was 43.5 and the critical ratio was 14.2. It is not concrete to approve the combined frequency distributions for all variables, and few data justify the assumption of multivariate normality. Therefore, if there is no major problem with a univariate normality test, it can be assumed that multivariate normality is satisfied (Collier, J. E., 2020). In summary, the measured variables in this study justified univariate normality, and thus, the validity of the math attitude instrument was satisfactory.

5.1 Findings and Analysis

According to Maydeu-Olivares, A., Shi, D., & Fairchild, A. J. (2019), the load factor for the newly developed scale must be exceeding 0.5. In this study, all items with lower factor loading values of 0.5 are eliminated from 'construction' to ensure unidimensionality,

parsimonious, incremental and absolute fit can be achieved. Analysis shows that 43 items were removed because they had a factor loading which less than 0.5. Through observation of the researchers, the item is not too weak but has a modest factor loading of between 0.3 – 0.49.

Table 3: The Latent Constructs Fitness Summary

Construct				Incremental		Parsimonious	Absolute
	Chisq	Df	P value	TLI	CFI	Chisq / df	RMSEA
belief	7116.13	6	0.000	-	1.00	1186.02	0.349
efficacy	197.72	5	0.000	0.970	0.990	39.54	0.063
effort	56.502	5	0.000	0.993	0.998	11.3	0.033

Table 3 above shows the fitness indices of all latent constructs in the model. Constructive mediators such as belief, efficacy and effort have a value of ChiSq/df which is more than 5.0. This construct model also has TLI and CFI values higher than 0.7 and RMSEA values less than 0.10 except belief factor. Therefore, additional and absolute fitness has also been achieved. All constructs have correlations of more than 0.70. It can be decided that discriminant validity had been accomplished and no finalized construct need to be terminated from the model. It can be concluded that three fitness are required in this modeling had been achieved. The ChiSquare / df value indicate in this model was not achieved a goodness of fit since the ChiSquare / df value is 39.3 which is higher than 5.0. However, RMSEA value is 0.063 which is below than 0.10 which was achieved a goodness of fit (Table 4 and Figure 2).

Table 4: Model of Fitness

Model	CMIN	DF	CMIN / DF	CFI	TLI	RMSEA
Default model	2829.863	72	39.304	0.953	0.931	0.063

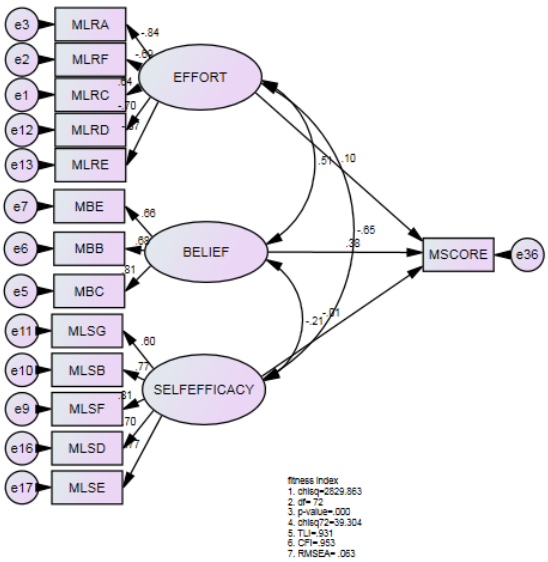

Figure 2: Measurement Model

6.0 CONCLUSION AND DISCUSSION

The result above shows that attitude towards mathematics (ATM) can be much more than just basic multiple choice checkers or simple free text comparison. The result differs from other approaches to assessment frequently referred to as 'attitude'. In our understanding ATM means:

- Mathematical belief, effort and self-efficacy are being made detectible, visible associated significantly towards mathematics achievement (MSCORE). Without this, a discussion about improving competencies in mathematics is fruitless.
- Students are permitted to follow their own attitude or strategy of solving problem rather than following a given recipe blindly (Hall, J., & Suurtamm, C., 2018).

Moreover, we are able to specify the characteristics that lead to these enhancements of ATM. Although our study is coming from different background, they share three common principles of ATM:

- The process of compiling a solution (MLRA-effort) to a test is recorded and validated.
- The process of finding a solution (MLSG-self-efficacy) is divided into discrete entities that make up a series of semantic events.
- The correctness of each step is not checked literally, but by testing each intermediate result for mathematical equivalence with the desire (MBE-belief) solution (Baruah, N., Ellis, E., Gill, M. & Greenhow, M., 2005).

We see the above principles as a starting point for a new paradigm for the design of ATM structures that take into account process of knowledge. Still, for a broader application of this paradigm there remain a number of open research questions. We consider the following problem crucial from a pedagogical point of view and they should be addressed in future result:

- We need a 'theory' of attitude towards mathematics, which describes categories of assertiveness in general (MLRF) and in special mathematical fields like algebra or geometry (MLRC). A similar classification is necessary (MLRD) for process skills (Jürges, H., Schneider, K., Senkbeil, M., & Carstensen, C. H., 2012).
- This theory needs to be extended to the level where processes are divided into discrete steps (MLSB). This involves, for instance a distinction of stages in the solution process, such as generating solutions, evaluating and selecting the appropriate strategy, planning (MLSF) and then undertaking an activity that solves the problem (MLSD) (Thomas, R., Ashton, B., Beevers, C., Edwards, D. and Milligan, C., 2004). For specific solution processes a further split-up to individual solution steps is necessary as in the case of solving linear systems of equations (MLSE).
- The single problem solving steps have to be related to mechanisms for identifying possible errors. A somehow general approach would be the description of extended solution spaces that could be exploited using automatic theorem proving (MBB) or unit tests (MBC) (Haworth, C., Kovas, Y., Harlaar, N., Hayiou-Thomas, M. E., Petrill, S. A., Dale, P. S., & Plomin, R., 2009).
- Error classes and patterns have to be identified on this discrete step level. If possible, these error classes of attitude should be independent of the specific subject and problems. This implies that we need a meta-description of semantic events (MLRE). It remains an open question, however whether we can identify problem solving strategies across different subjects (Godbout, N., Daspe, M. È., Runtz, M., Cyr, G., & Briere, J., 2019).

Finally, from a technical point of view there are still a number of problems to be solved, for instance: likewise, the beauty of mathematics is also emphasized. Introducing students the history of famous mathematicians or important mathematical event in the past may motivate students to appreciate the subject in a long term. Mathematics' essential value especially in belief, effort and efficacy applied indirectly or continuously during teaching and learning process contribute to personal building and nurturing of positive ATM. Besides, good values of attitudes are also introduced in the teaching and learning context. Assessments are performed to measure student achievements in tests and examinations as well as other sources which all provide useful information regarding student development and growth.

Declaration of Conflicting Interests

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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