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A Confirmatory Factor Analysis of Mathematics Beliefs Scale in a Malaysian Context

[1]Siti Mistima Maat, [2]Effandi Zakaria and [2]Norazah Mohd Nordin

[1]Mathematics Unit, Technical Foundation Section Universiti Kuala Lumpur Malaysia France Institute, Bangi, Selangor.
[2]Department of Educational Methodology and Practice, Faculty of Education Universiti Kebangsaan Malaysia, Bangi, Selangor.
[3]Department of Educational Foundation, Faculty of Education Universiti Kebangsaan Malaysia, Bangi, Selangor.

Abstract: Mathematics beliefs are an important element in strengthening the teaching and learning process among teachers. Previous research proposed that mathematics beliefs should be categorized into three dimensions that include beliefs about the nature of mathematics, beliefs about mathematics teaching, and beliefs about mathematics learning. This study aimed to validate a Mathematics Belief Scale (MBS) that consists of 36 items. The instrument was distributed to 254 mathematics secondary school teachers in one of the states in Malaysia. These teachers were required to respond to a five-point Likert scale instrument. Exploratory factor analysis and confirmatory factor analysis were used to examine the MBS using AMOS 16.0. All constructs revealed acceptable internal consistency reliability. A good model fit was found for mathematics beliefs measurement model using several fit index tests like CMINDF, GFI, CFI, TLI, and RMSEA. The findings showed that all fit indices criteria were fulfilled. It was also showed that acceptable construct reliability and variance extracted value were obtained.

Key word: Mathematics beliefs, confirmatory factor analysis, mathematics teachers, exploratory factor analysis

INTRODUCTION

Teachers' beliefs are considered as part of knowledge for teaching (Furinghetti, 2007), which plays a vital role in giving impact on teaching (NRC, 2001). As proposed by Thompson (1992), beliefs are related to teachers' practice and can be categorized into beliefs about the nature of mathematics, beliefs about mathematics teaching, and beliefs about mathematics learning. The three components of beliefs form the beliefs system, which influence mathematics teaching through social context, teachers' thinking process, and reflection (Ernest, 1989). How they behave in class is determined by the belief system rather than their knowledge (Shahvarani & Savizi, 2007). The conception of mathematics would affect on how teachers' knowledge is presented in class. The dynamic structure of beliefs can also be influenced by experience (Muijis & Reynolds, 2002), especially through the teaching process. Their teaching practice is determined by the mathematics beliefs that they hold. The beliefs are developed early through their experience as a student as well as pre-service teachers (Zakaria & Musiran, 2010). These beliefs give them ideas on how to manage their classroom and understand their students. This would lead to the decision in choosing their teaching practice according to their conception of mathematics beliefs. Choosing a traditional teaching practice by most teachers is related to the traditional beliefs about mathematics, which affects the students' performance (Lantin & Sangalang, 2009). Past research has also established the relationship between mathematics beliefs and teachers' teaching practices (Wilson & Cooney, 2002) that consequently relate to their knowledge.

The first belief system is teachers' beliefs about the nature of mathematics, which is defined as conceptions and preferences of the mathematics in the form of discipline of knowledge. Views of the nature of mathematics are also reflected in their teaching. Beliefs about mathematics teaching are defined as how mathematics is taught (Ernest, 1989). The teaching aspects are classified based on the delivery of mathematics knowledge in the classroom, which consisted of student-centered teaching (Manouchehri & Enderson, 2003) and teacher-centered teaching (Van der Sandt, 2007). Student-centered teaching allowed students autonomy in constructing mathematical knowledge through experience while doing mathematics (De Jong & Brinkman, 1997).

Corresponding Author: Siti Mistima Maat, Mathematics Unit, Technical Foundation Section Universiti Kuala Lumpur Malaysia France Institute, Bangi, Selangor.
E-mail: sitimistima@gmail.com

However, teacher-centered teaching transmits knowledge to learners, which is dominated by teachers. The learning process takes place as knowledge is being delivered, which results in creating the third belief system, beliefs about mathematics learning. Teachers believe that mathematics can be learned if students are able to relate to what they have learnt with previous knowledge (An *et al*., 2004). Thus, the importance of mathematics beliefs among teachers should be studied in order to understand the teaching practices in the mathematics classrooms. Hence, this study aimed to validate a Mathematics Belief Scale (MBS), which includes testing and validating using exploratory factor analysis (EFA) and a confirmatory factor analysis (CFA).

Methodology:

The researcher used stratified sampling technique in choosing the sample of the study. A total of 254 respondents participated in this study. The respondents are mathematics secondary school teachers in one of the states in Malaysia. Most of the teachers are female (79.9%), and only 20.1% of the sample are male teachers. Out of the 254 samples, 81.9% of them are Malays, 27% of them are Chinese, 6.7% are Indians, and the balance are from other ethnic groups. As for teaching experience, 124 (48.8%) teachers have more than ten years experience, and only 22 (8.7%) of them have between three to five years of teaching experience. The detailed information is shown in Table 1. The respondents were given a set of instruments, which consists of demographic information and Mathematics Beliefs Scale (MBS). They are required to answer 36 items of MBS with a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The instrument was administered by the researcher and the respondents were given ample time to answer the survey. The representative of each school collected the answered survey and returned them to the researcher.

The MBS was developed by Evans (2003), which consisted of 11 items of beliefs about the nature of mathematics, 12 items of beliefs about mathematics teaching, and 13 items of beliefs about mathematics learning. However, the number of items was reduced to 30 due to low factor loading during the EFA process. The difference in research setting has become the justification in testing the MBS among mathematics teachers in Malaysia. Prior to conducting the real data collection, the researcher conducted a pilot study with 101 respondents of mathematics school teachers. Comments and recommendations during this pilot study have been considered by the researcher in order to improve the instrument. The variability in cultural setting as well as checking the validity and reliability of MBS are required in this context of study. The issues of mathematics beliefs scale have been noted by Cerit (2010), especially those related to the robustness and adequacy of the scale. Furthermore, the focus of this research is not only on determining the mathematics beliefs among the selected samples but also include the relationship between the scale and other variables (Cerit, 2010).

Results:

The study used both exploratory factor and confirmatory factor analyses to validate the underlying hypothesized factor structure of MBS. The items of the MBS were represented by measured or observed variables.

Reliability:

All items were rated on a five-point Likert scale: 1 = strongly disagree, 2 = disagree, 3 = moderately agree, 4 = agree and 5 = strongly agree. The value of Cronbach alpha obtained should be at least 0.70 for any research using the survey method (Hair *et al*., 2010). The reliability coefficient of the MBS is 0.81 and each subscale has reliability value ranging from .71 to .81. Thus, MBS have an acceptable value of internal consistency for this study.

Exploratory Factor Analysis (EFA):

An exploratory factor analysis was performed using SPSS 16.0. The technique involved several processes in order to identify the factor viable structure. It is also to ensure that the factor consist of suitable item (Tabachnick & Fidell, 2001). The technique has to be applied to the collected data before fitting with the statistical models (Singer & Willett, 2003). EFA can be used to reduce the number of items in a particular construct so that the remaining items would be able to increase the variance and the reliability values. Furthermore, EFA helps to identify the dimensions that might be included in the constructs (Netemeyer *et al*., 2003). The EFA begins with the determination of the Kaiser Meyer-Olkin Measure of Sampling Adequacy (KMO) value that equals .85. The value was considered excellent based on the suggested criteria for KMO value by Hair and colleagues (2010). This indicates that the sampling was adequate in conducting the next stage of factor analysis.

Next, to fix the appropriate number of factors for the scale, the researcher used the eigenvalue rule and scree plot test (Kaiser, 1960 & Catell, 1966). The Barlett Test of Sphericity was significant (p=.00). On the basis of the analysis, 12 items had eigenvalues more than 1. However, the scree plot in figure 1 revealed that only three factors were retained. These criteria were used to perform varimax rotations by retaining the three factors with a cumulative percentage of variance of 34.46. The varimax rotation was applied because of the unrotated matrix showed that some of the factor loadings did not maximize the loading of every variable of a particular factor (Hair *et al*., 2010). Items with factor loading of more than .40 were retained since this would likely increase the reliability of the scale (Costello & Osborne, 2005). Only 17 items were considered in the MBS at the final stage of the EFA process. The results of the exploratory factor analysis revealed that Mathematics Beliefs scale yielded three factors for the respondent of the study. Selected items from MBS scale with their factor loadings are shown in Table 2.

Confirmatory Factor Analysis (CFA):

Confirmatory factor analysis plays the role of validating and finding the reliability of any measurement in most social science studies (Harrington, 2010). The researcher used AMOS 16.0 (Arbuckle, 2010) to perform CFA. The standardized output was used to report the parameter estimation of the model (Hashim & Sani, 2008). The measurement model of MBS contained both observed (measured) variables and latent constructs, which represent beliefs about the nature of mathematics, teaching, and learning. In order to achieve model fit, fit statistics tests like traditional chi-square test, the relative chi-square (CMINDF: the chi-square/degree of freedom), Tucker Lewis Index (TLI), Comparative Fit Index (CFI), Goodness of Fit Index (GFI), and Root Mean Square of Error Approximation (RMSEA) were chosen (Hair *et al*., 2010). The acceptable criterion for traditional chi-square is shown by non-significant result. The relative chi-square (CMINDF) must be between 1 and 5 in order to achieve the fitness of the model. The TLI, CFI, and GFI values should be in the range of 0 to 1. However, the RMSEA value should fall below 0.08 to indicate an acceptable fit to the data (Schumacker & Lomax, 2004).

Table 3 shows the results of the confirmatory factor analysis (CFA) on the three-factor model of MBS; CMINDF = 1.633, p = .020, and TLI, CFI, and GFI shows values of .920, .934, and .922, which reflect a close fit model respectively. The RMSEA value shows.049, which indicates that the model has a good fit.

As seen in Figure 2, the measurement model of MBS specifies the relations between observed variables and latent variables. The observed variables and the latent variables are represented by the boxes and the ellipses respectively. All loadings of items on each factor of MBS were above .40 and significant. The value of .40 is a common cut-off value which is typically used in any factor analyses (Hashim & Sani, 2008). The double-headed row represents the covariance, which also can be interpreted as correlation (Hair *et al*., 2010).

The covariance between beliefs about mathematics teachings and beliefs about the nature of mathematics shows the lowest value among all the covariances. The covariance between beliefs about the nature of mathematics and beliefs about mathematics learning is greater than the covariance between beliefs about mathematics teaching and mathematics learning. However, the covariances that exist between the observed variables are obtained from the modification index from AMOS output. The consideration on the modification has to be based on the theoretical framework with the intention of reducing the value of traditional chi-square.

The construct reliability for each factor of MBS is also calculated in order to fulfill the divergent validity criterion (Hair *et al*., 2010). The construct reliability is .85, .83, and .88 for beliefs about the nature of mathematics, mathematics teaching, and mathematics learning respectively. These values are acceptable since the cut-off point for composite reliability should exceed .70 (Hair *et al*., 2010).

Table 1: Respondent Profile.

Type	N	Factor	Frequency	Percentage (%)
Gender	254	Male	51	20.1
		Female	203	79.9
Race	254	Malay	208	81.9
		Chinese	27	10.6
		Indian	17	6.7
		Others	2	.8
Years of experience	254	1 - 3 years	48	18.9
		3 - 5 years	22	8.7
		5 - 10 years	60	23.6
		> 10 years	124	48.8

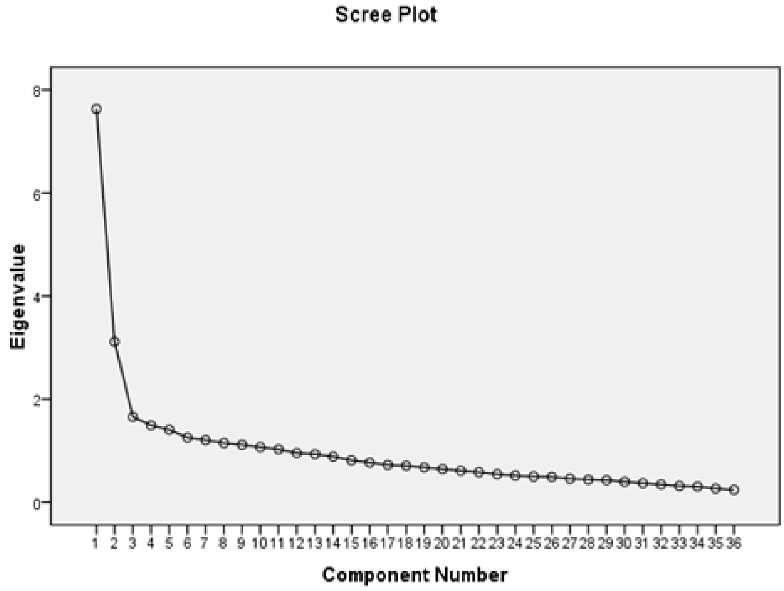

Fig. 1: Scree plot of MBS.

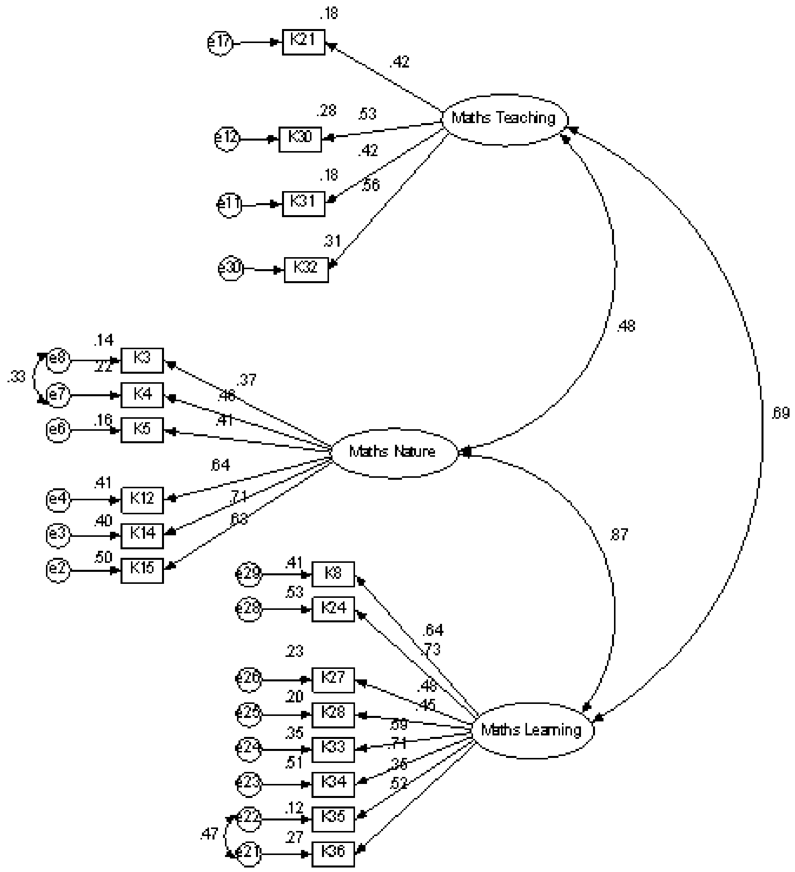

Fig. 2: The finalized measurement model of CFA.

Table 2: Selected items from MBS with factor loadings obtained from EFA process.

Item	Factor loading
K34: To be good in mathematics at school, understanding mathematical concept, principles, and strategies is important.	.707
K36: To be good in mathematics at school, being able to provide reasons to support the solution is important.	.691
K24: Learning mathematics is an active process.	.659
K33: To be good in mathematics at school, thinking in a sequential manner is important.	.657
K27: To solve most mathematics problems, you have to be taught the correct procedure.	.566
K35: To be good in mathematics at school, understanding how mathematics is used in the real world is important.	.554
K3: Mathematics should be learned as sets of algorithms or rules that cover all possibilities.	.592
K2: If students are facing difficulties, an effective approach is to give them more practice by themselves during the class.	.513

Table 3: The results of CFA on mathematics beliefs scale (n=254)

Fit Statistics	df	p	CMINDF	TLI	CFI	GFI	RMSEA
Value	127	.020	1.633	.920	.934	.922	.049

Discussion:

The analyses indicate three factors on MBS, which are consistent with Mahmud (2010) that involves 378 polytechnic lecturers in Malaysia. The measurement model has yielded three factors that include the nature of mathematics, mathematics teaching, and mathematics learning as proposed by Evans (2003). However, the items in the finalized MBS measurement model were not similar with the selected items by of Evans (2003). This can be seen from the finalized measurement model of MBS as shown in Figure 2.

At the beginning of the study, the measurement model consisted of 36 items, which have been reduced to 18 items because of loading factors value. The EFA and CFA analyses provide evidence to the reliability and validity of MBS. This is shown by the construct reliability as well as variance-extracted value that exceeds the suggested value. Therefore, the MBS can be replicated in future works with a wider sample range. This would direct to the betterment of the instrument, which can be used in measuring teachers' mathematics beliefs through testing and evaluation processes.

Based on the analysis, it was found that the covariance value that exist among the three factors of MBS is consistent with Shahvarani and Savizi (2007). Teachers' mathematics beliefs about the nature of mathematics can be integrated in their teaching and learning processes. Some aspects of the nature of mathematics are also found in teaching mathematics. For instance, the importance of mathematics in solving problems is very much related to the application of mathematics in real life, which is taught in class as well as out of the mathematics class. This shows that these teachers hold beliefs about mathematics as suggested by Ernest (1989). The result also shows high level of covariance between beliefs about the nature of mathematics and mathematics learning. Teachers are expected to indirectly convey their beliefs about the nature of mathematics when delivering topics in mathematics. The low-level of covariance between beliefs about the nature of mathematics and mathematics teaching is probably due to lack of teachers' emphasis on the importance of the nature of mathematics while teaching mathematics.

Conclusion:

The output of EFA and CFA for this study has shown the evidence of the reliability and the validity of the MBS. The acceptable model fit was achieved since all the chosen fit statistics conformed to the requirement. The analyses yielded evidence that MBS can be a useful scale to measure mathematics beliefs among teachers, especially in a Malaysian context. Since all the factors have good acceptable reliability value, each factor can be measured individually depending on the nature of the research. Likewise, the MBS measurement model from this study can be a starting point for further research.

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