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Pre-service Mathematics Teachers' Belief towards Mathematics; A Confirmatory Factor Analysis

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Abstract: The purpose of the study was to assess the construct validity and reliability of pre-service mathematics teachers' belief towards mathematics. The analysis of this study started by proposing four alternative models. The alternative models were compared to obtain the best fit model and its validity and reliability were evaluated by looking at the factor loadings and the proportion of variance. Based on the factor loadings, the hierarchical model has moderate standardised structure coefficients from 0.272 to 0.658 which indicates that they have the stronger indication that the factors represent the unobserved construct. The best alternative model is the three factors hierarchical model (χ^2=1.081; GFI=0.974, AGFI=0.931, TLI=0.944, CFI=0.970; RMSEA=0.028). The reliability for the best-fit model of the factors ranges from 0.143 to 0.411 which belongs to mediocre and low reliability. The variance explained by the TBM factors and TBM construct; TBMF1 (39.4%), TBMF2 (28.7%), TBMF3 (8.5%), TBM (26.7%), were quite low which indicated that more inaccuracy endures in the items than the variance defined by the unobserved construct established on the factors. However, due to the model fit and the structure coefficients which are close and greater than 0.4, three factors reflecting the Teachers' Beliefs about Mathematics construct were retained for further investigation.

Keywords: pre-service mathematics teachers, belief towards mathematics, confirmatory factor analysis

INTRODUCTION

Beliefs were grounded in terms of self-efficacy in the social cognitive theory by Bandura (1986) who showed that people's behaviour is significantly affected by confidence in their capability to perform it. Beliefs would influence people's preference of activities, the endeavour to prepare, and the amount of time they maintain the effort in the activities. Richardson (1996) defined belief as a concept of understandings, assumptions, or preposition of the facts which are perceived to be true.

Bandura's theory was well received in educational research related to teaching and its efficacy, since a number of studies indicated beliefs as an important factor in the decision on how the teachers teach (Ernest, 1989; Schunk & Pajares, 2010; Wilkins, 2008). The self-efficacy belief was also indicated depending on context and subject matter, so that it need to be broadened to particular field (Bursal & YiĞİT, 2012). In this study, beliefs were related to the subject of mathematics, which included mathematical content and teaching. Perry et al. (1999) stated that for a mathematics teacher, beliefs towards mathematics are important because they not only influence how a teacher assumes about, addresses, and pursues mathematical tasks, but it also influences how the teacher studies and organises mathematical instructions. Therefore, beliefs towards mathematics could not be considered apart from beliefs about mathematics learning. Those beliefs would direct teachers in their decision taking and teachers' strategies for application. In addition, Thompson (1984) mentioned that teachers'

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interpretation of mathematics are related to their perspectives towards mathematics learning which would lead teachers' instructional behaviour in the classroom.

Studies investigated teachers' belief towards mathematics have been conducted in several countries. The research established instruments which indicated a good quality in measuring teachers' belief towards mathematics. Perry et al. (1999) created a questionnaire consisted of six items with two main factors, transmission and child-centeredness. The instrument showed adequate evidence to be used as assessment tools. However, there is no further research examining this instrument in Indonesian context. Therefore, it is necessary to evaluate the instruments to ensure that it is valid and reliable for Indonesian pre-service mathematics teachers.

Construct validity could be analysed through several ways. Confirmatory Factor Analysis (CFA) is a structural equation model (SEM) used to deal with the relationship between measurement models or the association between observed variables and latent variables. Different from exploratory factor analysis (EFA), CFA needs researchers to determine the model in advance. Accordingly, researchers who want to do CFA are required to have a substantial theoretical foundation. CFA puts more attention on theory and hypothesis testing, as well as many other possibilities. In addition, CFA encouraged to carry out before SEM, since it would be used to explore the psychological measurement of the instruments, construction verification, method influences, and invariance evaluation (Brown, 2014).

The aim of the study was to assess the construct validity and reliability of pre-service mathematics teachers' belief towards mathematics. The findings of the study would be the review to establish a different instrument or to modify the existing items related to pre-service mathematics teachers' belief towards mathematics. The article will also provide confirmation to strengthen the theory found in previous studies.

METHOD

This study was a quantitative survey design with the type of cross-sectional study which examined the validity in belief towards mathematics from a questionnaire for Indonesian pre-service mathematics teachers. The participants in our study were pre-service teachers who will be mathematics school teachers at two teachers' universities in Indonesia. The number of total participants in this study was 106 ($n = 106$).

This study adopted the teachers' beliefs toward mathematics scales (TBM) from Perry et al. (1999) who associated teachers' attitudes with teachers' beliefs in the theoretical framework to create the six-items of the instrument (from TBM1 to TBM6). Every item has four levels of agreement represented by a four-point Likert scale: strongly disagree (1), disagree (2), agree (3), and strongly agree (4). A confirmatory factor analysis (CFA) in the previous study was conducted to examine the validity of the scale, yielding two factors of belief related to child-centeredness and the transmission of ideas with factor loadings ranging from 0.20 to 0.51 for the first factor and from 0.15 to 0.53 for the second factor. This instrument was appropriate for this study so that there was no change in the items.

This study uses SPSS AMOS Graphics to describe alternative models and examine the fit of each proposed model against the sample data. First, based on logic, theory, and concept proposed by instrument developer, Four possible factor structure substitution models are proposed. Without reassigning the model, several goodness-of-fit indicators are used to evaluate the sample data. Second, confirmatory factor analysis (CFA) is applied to examine the validity and reliability of the factors and items in the selected model. Four alternative models were proposed for this study. Model 1 hypothesises one-factor model (OFM). Model 2 is the three orthogonal factors model (3-OFM). Model 3 hypothesised three correlated factors model (3-CFM). Model 4 is the hierarchical model (HM).

Hooper, Coughlan, & Mullen (2008) stated the goodness-fit-statistics such as chi-square (CMIN), Normed-fit Index (NFI), Relative Fit Index (RFI), Tucker-Lewis Index (TLI), Comparative

Fit Index (CFI), Root mean square error of approximation (RMSEA). The value of chi-square is sensitive to the sample size and low CMIN is relative to degrees of freedom with an insignificant p value ($p > 0.05$). The acceptable value for NFI, RFI, TLI, and CFI to be considered as the well-fitting model is greater than 0.95, meanwhile for RMSEA, the value is less than 0.07.

Doll, Xia, & Torkzadeh (1994) declared that the validity of the observed variables can be indicated by the factor loadings of manifest variables (items) on the latent variables (factors). The greater the factor loadings, the more robust indication that the factors represent the construct. The reliability of the overall instrument can be estimated by the coefficient of determination, and the items and factors by the proportion of variance (R-square). The greater the value, the better the reliability.

RESULT

The six items of the Teachers' Beliefs about Mathematics construct (TBM) ($n = 106$) were subjected to Principle Component Analysis (PCA) and Confirmatory Factor Analysis (CFA). The analysis was begun by the inspection of correlation in order to explore the relationships among the six-items. It can be seen from table 1 that the strongest relationship pairs are between TBM1 & TBM2 ($r = 0.397$), TBM4 & TBM6 ($r = 0.245$), and TBM5 & TBM3 ($r = 0.084$) with the other correlations from -0.086 to 0.148. The Kaiser-Meyer-Olkin value indicated 0.479 and Bartlett's sphericity test has achieved statistical significance and supports the decomposability of the correlation matrix. Examination of the scree plot revealed a sharp gap after the third part. PCA shows that there are three parts with eigenvalues exceeding 1, which explain 26.0%, 19.7% and 17.4% of the variances subsequently. The maximum variance orthogonal method is used to evaluate under the expectation that there are no related components. Therefore, using scree test of Cattell (1966), it was determined to keep three factors for the next analysis.

Table 1. Item correlation of Teachers' Belief towards Mathematics (TBM) construct ($n = 106$)

	TBM3	TBM5	TBM6	TBM4	TBM2	TBM1
TBM3	1.000	-	-	-	-	-
TBM5	0.084	1.000	-	-	-	-
TBM6	0.042	0.000	1.000	-	-	-
TBM4	0.025	0.051	0.245	1.000	-	-
TBM2	0.130	0.150	0.096	0.122	1.000	-
TBM1	0.025	0.051	0.148	−0.086	0.397	1.000

Table 2. Questionnaire Items of Teachers' Beliefs about Mathematics construct

Factor	Common Theme	Item	
TBMF1	Mathematical problem solving	TBM1	Mathematics is computation
		TBM2	Mathematics problems given to students should be quickly solvable in a few steps
TBMF2	Comparison	TBM4	Mathematics is no more sequential a subject than any other
		TBM6	Right answers are much more important in mathematics than the ways in which you get them
TBMF3	Philosophical definitions of mathematics	TBM5	Mathematics is a beautiful, creative and useful human endeavour that is both a way of knowing and a way of thinking
		TBM3	Mathematics is the dynamic searching for order and pattern in the learner's environment

Table 3. Goodness-of-Fit Indicators for Teachers' Beliefs about Mathematics construct ($n = 106$)

Alternative Model	CMIN	df	CMIN/df	GFI	AGFI	TLI	CFI	RMSEA
OFM	11.984	9	1.332	0.968	0.925	0.771	0.863	0.056
3-OFM	11.447	12	0.954	0.925	0.939	1.032	1.000	0.000
3-CFM	88.563	7	12.652	0.868	0.605	−7.049	0.000	0.333
3-HM	8.644	8	1.081	0.974	0.931	0.944	0.970	0.028

Based on the PCA, three factors within the Teachers' Beliefs about Mathematics constructs (TBM) were found. Each factor represented a common theme of the items, that is, mathematical problem solving (TBMF1; TBM1 & TBM2), comparison (TBMF2; TBM4 & TBM6), and philosophical definitions of Mathematics (TBMF3; TBM3 & TBM5).

To obtain the best model for Teachers' Beliefs about Mathematics construct (TBM), four alternative models are proposed, such as single factor model (OFM), three orthogonal factors model (3-OFM), three correlated factors model (3-CFM), and three factors hierarchical model (3-HM). Table 3 compares the model fit indices of the alternative models. The expected values of a well-fitting model are greater than 0.95 (Schreiber et al., 2006) or at least 0.90 (Hooper et al., 2008) for GFI, AGFI, TLI, and CFI and less than 0.06 for RMSEA (Schreiber et al., 2006). It can be seen from table 3 that the TLI value of the 3-orthogonal factors model is 1.032 and that of the 3-correlated factors model is -7.049, whereas the acceptable value for TLI is between 0 and 1 (Hooper et al., 2008; Schreiber et al., 2006), then those models are not accepted. It is also shown that the 3-factors hierarchical model has the better values than the 1-factor model, indicated with the lowest value of Chi-Square (χ^2=1.081), the immense values of GFI, AGFI, TLI, and CFI $(0.974, 0.931, 0.944, 0.970)$ and small value of RMSEA (0.028). Thus, the best model is the three factors hierarchical model which can be seen in figure 1.

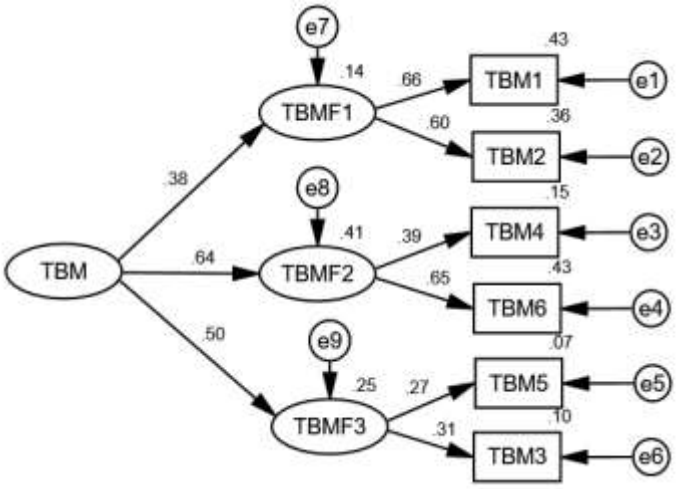

Figure 1. Three factors hierarchical model for teachers' beliefs about mathematics

Table 4. Factor Loadings for Teachers' Beliefs about Mathematics construct ($n = 106$) (Three Factors Hierarchical Model)

Observed Variable			Latent Variable			
Items	Factor Loadings	Squared Multiple Correlation	Factors	Std. Structure Coefficient	Squared Multiple Correlation	Average Variance Extracted
TBM1	0.658	0.433	TBMF1	0.378	0.143	39.4%
TBM2	0.596	0.355				
TBM4	0.387	0.150	TBMF2	0.641	0.411	28.7%
TBM6	0.652	0.425				
TBM5	0.272	0.074	TBMF3	0.497	0.247	8.5%
TBM3	0.310	0.096				
			TBM			26.7%

The factor loadings, Squared Multiple Correlations (SMC), and Average Variance Extracted (AVE) for the Teachers' Beliefs about Mathematics construct are presented in table 4. The higher the value of the range indicates the stronger evidence that the manifest variables represent the unobserved construct (Doll et al., 1994). Table 4 shows that the construct has the factor loadings of items ranging from 0.272 to 0.658 and only half of the items are higher than 0.5, with indication of lower bound reliability of the measure; TBM1 (0.433) and TBM5 (0.074) are the greatest and the smallest, subsequently. However, the whole items were retained due to the model fit and the minimum number of observed variables per one latent variable, which is two items (Kenny et al., 1998).

Teachers' Beliefs about Mathematics construct also has moderate standardised structure coefficients. Mathematical problem solving (TBMF1) obtains the least standardised structure coefficient (0.378) with decreased level reliability of 0.143. Meanwhile comparison (TBMF2) has the greatest value (0.641) and greatest lower bound reliability (0.411). The variance defined by the TBM factors and TBM construct; TBMF1 (39.4%), TBMF2 (28.7%), TBMF3 (8.5%), TBM (26.7%), were quite low. It indicates that on the average, more inaccuracy endures in the items than variance defined by the unobserved construct established on the factors. However, due to the model fit and the structure coefficients which are close and greater than 0.4 (Walker & Madden, 2008), three factors reflecting the Teachers' Beliefs about Mathematics construct were retained for further investigation.

DISCUSSION

According to the analysis, the construct of Teachers' Beliefs about Mathematics (TBM) has three factors. The common theme of each factors was derived to elaborate the underlaying variables observed by each of the items. A few distinct findings have been found by this study.

The first factor has two items i.e. TBM1 "Mathematics is computation" and TBM2 "Mathematics problems given to students should be quickly solvable in a few steps". In the previous study, TBM1 and TBM2 are included to transmission. Transmission refers to a conventional view that a skill and knowledge is transferred from teacher to students (Godino et al., 2016; Perry et al., 1999). In this research, TBM1 and TBM2 are considered as mathematical process and operation. The finding demonstrates that problem solving and transmission cross at a point. This first factor has the lowest representation to the main construct whereas the two observed variables have moderate effect. TBM1 and TBM2 represent mathematics problem solving correctly. Therefore, the conclusion means that problem solving does not strongly represent teachers' belief towards mathematics.

The third factor also consists of two items; TBM5 "Mathematics is a beautiful, creative and useful human endeavour that is both a way of knowing and a way of thinking" and TBM3 "Mathematics is the dynamic searching for order and pattern in the learner's environment". Based on the previous study, both items belong to child-centeredness which is defined as students as the main actors of mathematics learning by constructing their own concept of mathematics (Isikoglu et al., 2009; Perry et al., 1999). The general idea between those two items is philosophical definitions of mathematics. The result indicates that child-centeredness associates with philosophical definitions of mathematics. This third factor moderately reflects the main construct, whereas the two items does not sharply present the factor.

A different finding is indicated by the second factor composed from two items, TBM4 "Mathematics is no more sequential a subject than any other" and TBM6 "Right answers are much more important in mathematics than the ways in which you get them". The general theme for this aspect is comparison. However, in the previous study, TBM4 was categorised as child-centeredness meanwhile TBM6 included in transmission. TBM4 was determined to contrast between mathematics and the other subjects, at the same time TBM6 was seen to consider the preference while doing mathematics. The second factor has the highest factor loading among the other factors. In conclusion,

comparison in term of subject and doing mathematics strongly represents teachers' belief towards mathematics.

CONCLUSION

Based on the factor loadings, the hierarchical model has moderate standardised structure coefficients from 0.272 to 0.658 which indicates that they have the stronger indication that the factors represent the unobserved construct. The best alternative model is the three factors hierarchical model (χ^2=1.081; GFI=0.974, AGFI=0.931, TLI=0.944, CFI=0.970; RMSEA=0.028). The reliability for the best-fit model of the factors ranges from 0.143 to 0.411 which belongs to mediocre and low reliability. The variance explained by the TBM factors and TBM construct; TBMF1 (39.4%), TBMF2 (28.7%), TBMF3 (8.5%), TBM (26.7%), which indicated that more inaccuracy endures in the items than the variance defined by the unobserved construct established on the factors. However, due to the model fit and the structure coefficients which are close and greater than 0.4, three factors reflecting the Teachers' Beliefs about Mathematics construct were retained for further investigation.

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