A Scale for Measuring Teachers' Mathematics-Related Beliefs: A Validity and Reliability Study

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The purpose of this study was to develop and validate a scale of teacher beliefs related to mathematics, namely, beliefs about the nature of mathematics, mathematics teaching, and assessment in mathematics learning. A scale development study was used to achieve it. The draft scale consisted of 54 items in which 16 items related to beliefs about the nature of mathematics, 23 items related to beliefs about the teaching of mathematics, and 15 items related to beliefs about assessment in mathematics learning. At the first phase, 252 primary school teachers participated and exploratory factor analysis (EFA) was performed to evaluate the structure of the scale factor. There were two factors at each scale resulted from the analysis. At the second phase, 350 primary school teachers participated and confirmatory factor analysis (CFA) was performed to confirm the factors resulted from the EFA. The result of CFA indicated that the established model had sufficient fit indices. In addition, each factor had an adequate internal consistency coefficient, which was in the range of 0.715–0.787. Thus, this scale could be a satisfactory tool to assess teachers' mathematics-related beliefs. Subsequent studies could combine these three scales into an integrated scale, to simplify statistical analysis.

Key words: mathematics-related beliefs, primary school teachers, scale development, validation studies

INTRODUCTION

Several researchers were in common agreement that practices and behaviors of teachers in classrooms could be attributed to their own beliefs (Purnomo, Suryadi, & Darwis, 2016; Wilkins, 2008). Purnomo et al. (2016) found that pre-service teachers who hold belief that mathematics is a subject that has relevance to context and environment of students, they could make effort to present mathematical content in such a way that could be imagined by their students. In contrast, teachers who hold beliefs that solving mathematical problems must be in accordance with fixed rules and procedures, they tend to emphasize their practices on it. This type of practices is mostly known as instrumental teaching which might impede students to learn mathematics meaningfully as it heavily focuses on developing procedural knowledge devoid of understanding. As a result, students often make error when mathematical procedure is not fulfilled (Purnomo, Kowiyah, Alyani, & Assiti, 2014). Therefore, it makes sense that the focus of teacher education programs is to build teachers' belief systems (Jao, 2016; Shinde & Karekatti, 2012), especially to improve mathematics learning process.

In recent decades, there has been concern about studies regarding building beliefs and development of mathematical knowledge for teaching (e.g. Lui & Bonner, 2016; Tatto et al., 2008). Drageset (2010) and Holm and Kajander (2012) revealed that beliefs and the knowledge are related to and influenced each other in teacher professional development. It might affect quality of teaching and subsequently impact on students achievement in mathematics learning (Kajander, 2007).

Exploring teachers' belief is important step for developing policies and or obtaining an effective approach in teacher education programs. In Indonesia, teacher education programs has not focused on building teachers' belief systems related to mathematics (Purnomo et al., 2016). In addition, research examining teachers' belief systems related to mathematics in Indonesia is yet to be conducted. Thus, the study focus on developing instruments to assess teachers' belief systems related to mathematics in Indonesia.

Some studies demonstrate different opinions about the most appropriate method to assess teachers' beliefs in mathematics. Leder and Forgasz (2002) summarized some of methods that can be used such as interviews, questionnaires, observation, analysis of journal entries, reflections, and post-lesson conferences. In mathematics education research, a clinical interview is common method to explore teacher beliefs. However, this method is limited to a small sample, so it is poor in describing tendency of mathematics-related beliefs that are held by teachers on a large scale. Thus, questionnaires have become one of the major instruments appropriate to describe the mathematics-related beliefs of teachers on a large scale.

There were several studies that developed a scale of teacher beliefs, such as Brown and colleagues (Brown, Hui, Yu, & Kennedy, 2011; Brown & Remesal, 2012), who developed a scale of teacher beliefs about assessment. In addition, Barkatsas and Malone (2005) developed a scale of beliefs about nature, teaching and learning mathematics for secondary school teachers. However, studies of exploring teachers beliefs about nature of mathematics, teaching and learning, and assessment in an integrated manner are still limited. Therefore, this study aims to develop a scale for assessing teacher beliefs related to mathematics, which consists of beliefs about the nature of mathematics, teaching of mathematics, and assessment in mathematics learning. Our scale could be used to describe the mathematics-related beliefs of teachers on a large scale.

CONTEXT AND LITERATURE REVIEW

Arbitrary construct of beliefs has led many researchers to define and draw conclusions differently (Purnomo et al., 2016; Savion, 2009). Some researchers (e.g. Furinghetti & Pehkonen, 2002; Purnomo et al., 2016) agree that belief can be in the cognitive domain if we view relationship between beliefs and knowledge. On the other hand, when we view beliefs as a reaction to a particular situation, we assume that beliefs is associated to affective domain of an individual. In this context, knowledge can be categorized into objective knowledge and subjective knowledge (Ernest, 1991; Furinghetti & Pehkonen, 2002). Objective knowledge is knowledge that is accepted by certain community, while subjective knowledge is knowledge that is created or interpreted by individuals and does not have to be evaluated by others. Therefore, beliefs could be explained as subjective knowledge of an individual based on his/her experience and expressed with propositional attitudes, views and perceptions for the value of truth (Purnomo et al., 2016).

Teachers' beliefs related to mathematics encompass their beliefs about the nature of mathematics, mathematics teaching (and learning), and assessment. Beliefs about the nature of mathematics comprise an individual's subjective knowledge of mathematics as a discipline (Beswick, 2012; Thompson, 1992), so this belief is related to an individual's perspective of the philosophy of mathematics. Meanwhile, teacher beliefs about teaching mathematics comprise the teacher's subjective knowledge on the various types and steps of teaching, meaning teaching and learning, the role of teachers and students in learning, how students learn mathematics, and classroom activities related to the teaching of mathematics (Boz, 2008; Thompson, 1992). The implication is that teacher beliefs about learning become an integral part and a subset of beliefs about teaching. According to Purnomo et al. (2016), teacher beliefs about learning are always explicitly linked with how to make students learn the best. Therefore, we only use the term "teaching" for the case of teacher beliefs. Finally, beliefs about assessment refer to the subjective knowledge of teachers regarding the nature, essence, and/or purpose of assessment in mathematics learning (Brown & Gao, 2015; Suci & Purnomo, 2016).

We use another aspect as a basis to develop a scale of teacher beliefs related to mathematics. They are interdependent and have their respective positions in guiding the direction and purpose of the teacher in mathematics classes. For example, for teachers who believe that mathematics is static or has absolute truth (that includes a set of rules, facts, or procedures used to obtain a correct answer), their belief in teaching leads to a transmission model of teaching that is characterized by exposure, drills, and memorization, known as instrumental teaching. As a result, assessment is more likely to be seen as a way to give punishment and verification.

METHOD

A scale development study was selected to develop an instrument that adequately measures the teachers' mathematics-related beliefs. The procedures were as follow (a) defining and specifying the construct being measured, (b) generating an item pool, (c) providing and considering the study of experts on initial item pool, (d) refining and validating scale, (e) evaluating the items (DeVellis, 2017; Wymer & Alves, 2013). Furthermore, explanation related to participants, instrument and procedures, and data analysis can be seen in detail below.

Participant

The population of the research is primary school teachers in Jakarta in the 2015/2016 academic year. The participants in this research were divided into two independent samples. The participants in the first sample consist of 252 primary school teachers in Jakarta, who were selected conveniently. This technique have been selected for some benefits, including less cost and time-consuming, and ease of administration (McMillan & Schumacher, 2006). They are 19.8% male and 79.4% female, while the rest had no information. The participants in the second sample consist of 350 teachers from 75 different primary schools in East Jakarta. Initially, out of six cities in Jakarta, one city was selected conveniently. Then schools in the city were selected randomly. From those schools, several teachers were picked up conveniently as participants. They are 80.9% female and 17.5% are male, while 1.5% had no information. The sample size for both groups was more than the acceptable threshold for factor analysis which was equal to 200 (Barrett, 2007; Pituch & Stevens, 2016).

Instrument and Procedures

Studies related to beliefs (i.e. Beswick, 2005; Brown, 2004; Charalambous, Philippou, & Kyriakides, 2002; Genc, 2005; Op't Eynde & De Corte, 2003; Tatto et al., 2008; Van Zoest, Jones, & Thornton, 1994) are used to develop the questionnaire items. The Questionnaire was classified into four parts: questions about teacher demographics, beliefs about the nature of mathematics (BN-M), beliefs about the teaching of mathematics (BT-M), and beliefs about assessment in mathematics learning (BA-M). The draft scale includes 54 items using six-point Likert scales ranging from 1 (strongly disagree) to 6 (strongly agree). The draft scale was written in Bahasa Indonesia. The composition of each subscale consists of 16 items BN-M, 23 items BT-M, and 15 items BA-M. After preparing the questionnaire items, the content validity was qualitatively performed with the involvement of two experts hold doctorates in the field of mathematics education and one expert hold doctorates in the field of educational research and evaluation. Two experienced teachers were also involved in this research. Analysis and revisions were performed based on advice from experts.

Data Analysis

Analysis of the data of BN-M, BT-M, and BA-M was conducted separately. This allowed researchers to classify indicators into the respective appropriate dimensions. In addition, it can also be used for further research interests related to the consistency between them. The data obtained from the first group were analyzed using Exploratory Factor Analysis (EFA) aided IBM SPSS statistical software version 21. The EFA procedure uses principal components analysis (PCA) and two common methods: varimax and promax. Both are compared to obtain the best possible result. To determine the number of factors, we look at the Kaiser criteria, screening plot, and interpretation of each factor. The construct was developed from the first group of data, further confirmed using Confirmatory Factor Analysis (CFA) with the help of statistical software SPSS AMOS version 22. The Maximum Likelihood (ML) method with Bollen-Stine bootstrapping with 500 samples and bias-corrected bootstrap confidence intervals at 90% was employed as an alternative for data that violate the assumption of normal (Byrne, 2013; Nevitt & Hancock, 2001). Fit indices for the model using several statistical criteria with a threshold in each are shown in Table 1, i.e. Normed Chi-Square (NC), Root Mean Square Error of Approximation (RMSEA), Standardized Root Mean Square Residual (SRMR), Goodness-of-Fit Statistic (GFI), Adjusted Goodness-of-Fit Statistic (AGFI), Normed Fit Index (NFI), Tucker-Lewis Index (TLI), and the Comparative Fit Index (CFI).

Table 1. Threshold measures for fit indices model

Index	**Threshold**	
	Good Fit	**Acceptable fit**
NC	$1 \leq NC \leq 2$	$2 \leq NC \leq 3$
RMSEA	≤ 0.05	$0.05 < \text{RMSEA} \leq 0.08$
SRMR	≤ 0.05	$0.05 < \text{SRMR} \leq 0.08$
GFI	≥ 0.95	≥ 0.90
AGFI	≥ 0.95	≥ 0.90
NFI	≥ 0.95	≥ 0.90
CFI	≥ 0.95	≥ 0.90
TLI	≥ 0.95	≥ 0.90

Furthermore, the construct validity (i.e. convergent and discriminant validity) was examined. This can be evaluated by how well the coefficients of standardized factor loading, composite reliability (CR) and average variance extracted (AVE) are generated. A coefficient of 0.4 for standardized factor loading, 0.7 for CR, and 0.5 for AVE is an adequate limit for each of these measures. The discriminant validity can be evaluated by comparing the square root of AVE for any two constructs and the correlation estimate between the same construct (Abdullah, Marzbali, Woolley, Bahauddin, & Tilaki, 2014; Hair, Black, Babin, & Anderson, 2010). In addition, Hair et al. (2010) state that discriminant validity can also be evaluated by comparing AVE with the maximum shared squared variances (MSV) and the average squared shared variances (ASV). Finally, the internal consistency of each dimension for each subscale of beliefs is calculated using Cronbach's alpha. A coefficient of 0.6 is used as the limit for adequate internal consistency (Clark & Watson, 1995).

FINDINGS

Data Screening

Prior to the EFA and CFA, data screening was performed by checking the missing data, the normality of the data, and outliers. Multiple imputation methods is a recommended way to cope with missing data (Fichman & Cummings, 2003; Schlomer, Bauman, & Card, 2010). Furthermore, transformation was selected to normalize the data. Data for EFA met the criteria of normal, while for the data for the CFA, only the scale of BN-M is normally distributed. Therefore, for the data is not normal: it will be reported with the p-value from Bollen-Stine bootstrapping (Byrne, 2013; Loehlin, 2004).

Analysis of the matrix correlation for each dimension (i.e. BN-M, BT-M, and BA-M) was performed with the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy; the results were 0.693, 0.822, and 0.903 respectively. On the other hand, Bartlett's test of sphericity produces a p-value < 0.01 for each subscale.

Beliefs about the Nature of Mathematics

EFA of the BN-M

An iterative process of PCA with a varimax method to construct BN-M produced two components or factors. The solution was calculated from 46.034% of the total variance, 10 of the 16 items were used to describe both factors. Each of the items had significant factor loading because it was in the range of 0.536–0.759, i.e. above 0.32 (Tabachnick & Fidell, 2007). We named each factor based on the relationship between items and the relevant literature (Ernest, 1991, 1998; Hersh, 1997; Op't Eynde & De Corte, 2003). Factor 1 was associated with the view of mathematics as relevant objects; factor 2 was associated with dynamic views about mathematics. However, both factors were equally related to a view of social constructivism in mathematics, so as to identify traditional beliefs about mathematics that can be measured by looking at the opposite of the two factors. Coefficient alpha internal consistency estimates for the two factors were 0.709 and 0.651 for relevant and dynamic factors respectively.

CFA for BN-M

CFA by the ML method was performed with model refinement twice, the output for the final model was $\chi^2 = 30.138$; df = 24; p = 0.180; NC = 1.256; RMSEA = 0.028; SRMR = 0.044; GFI = 0.978; AGFI = 0.960; NFI = 0.961; TLI = 0.988; CFI = 0.992. The model fit was good. A summary of the analysis results is given in Table 2.

Table 2. Fit Indices and BN-M Model Comparison

	Good Fit	Acceptable Fit	Model 0	Model 1	Model 2
NC	$1 \leq NC \leq 2$	$2 \leq NC \leq 3$	3.003	2.440	1.256
RMSEA	≤ 0.05	0.05 < RMSEA ≤ 0.08	0.079	0.067	0.028
SRMR	≤ 0.05	0.05 < SRMR ≤ 0.08	0.066	0.053	0.044
GFI	≥ 0.95	≥ 0.90	0.936	0.954	0.978
AGFI	≥ 0.95	≥ 0.90	0.897	0.921	0.960
NFI	≥ 0.95	≥ 0.90	0.877	0.918	0.961
CFI	≥ 0.95	≥ 0.90	0.885	0.950	0.988
TLI	≥ 0.95	≥ 0.90	0.913	0.949	0.992

Note:
Model 1: Removal of item dynamic 1
Model 2: Pairs e9 and e10; e8 and e10; e8 and e9; e6 and e9; e6 and e8; e6 and e7 used as free parameters

Construct validity of the BN-M

The analysis was continued by assessing the construct validity. Standardized factor loading for each variable in the construct beliefs about the nature of mathematics is in the range 0.53–0.75. The CR values for the two factors were 0.75 and 0.77 for dynamic and relevant factors respectively. Both values were greater than the recommended threshold value. The AVE value of 0.5 was gained by the dynamic factor, but the value gained less than satisfactory to the relevant factor, i.e. 0.36 < 0.5 as the recommended threshold. Nevertheless, Malhotra and Dash (2011) state that the convergent validity was adequate though only based on CR. Based on the literature, it can be interpreted that the construct beliefs about the nature of mathematics have adequate convergent validity. The discriminant validity of each of the factors was also adequate, as indicated by the value of AVE being larger than the MSV and ASV.

Reliability of BN-M

The internal consistency of each factor is greater than the recommended coefficient of 0.6. The dynamic factor has an alpha coefficient of 0.749 and 0.787 for the relevant factors. The analysis was also performed by looking at the item-corrected item-total correlation (CITC) with the result that all the items were insufficient criterion items that were 0.3 or more.

Belief about Teaching of Mathematics

EFA of BT-M

An iterative process of PCA with varimax rotation method resulted in two factors. The solution was calculated from 38.654% of the total variance and 20 of the 23 items used to describe both factors. Each of the items had a significant factor loading. Naming each factor is based on the relationship between items and is associated with the relevant literature (Cooper, 1993; Jonassen, 1991; Purnomo et al., 2016). Factor 1 was associated with a relational view of mathematics teaching and factor 2 with an instrumental view. The alpha coefficient estimates of internal consistency were 0.844 and 0.767 for the relational and instrumental factors, respectively.

CFA of BT-M

CFA by the ML method with Bollen-Stine bootstrapping was performed with three-time improvement. The output obtained for the final model of χ^2 (38) = 65.687; p = 0.03; NC = 1.729; RMSEA = 0.048; SRMR = 0.045; GFI = 0.965; AGFI = 0.939; NFI = 0.915; TLI = 0.945; CFI = 0.962 indicated an acceptable model fit.

Table 3. Fit Indices and BTM Model Comparison

	Good fit	Acceptable fit	Model 0	Model 1	Model 2	Model 3
NC	$1 \le NC \le 2$	$2 \le NC \le 3$	2,611	2,575	2,024	1,729
RMSEA	≤ 0.05	0.05 < RMSEA ≤ 0.08	0.071	0.700	0.059	0.048
SRMR	≤ 0.05	0.05 < SRMR ≤ 0.08	0.074	0.062	0.058	0.045
GFI	≥ 0.95	≥ 0.90	0.879	0.920	0.940	0.965
AGFI	≥ 0.95	≥ 0.90	0.849	0.890	0.912	0.939
NFI	≥ 0.95	≥ 0.90	0.707	0.813	0.858	0.915
CFI	≥ 0.95	≥ 0.90	0.768	0.850	0.896	0.945
TLI	≥ 0.95	≥ 0.90	0.793	0.875	0.919	0.962

Note:

Model 1 : Removal of items relational 11, relational 12, relational 14, relational 23, relational 13, and relational 17

Model 2 : Pairs e15 and e16; e10 and e13; e10 and e12; e1 and e13; e1 and e12 used free parameters

Model 3 : Removal of items relational 15, relational 16, and instrumental 4

Construct validity of BT-M

The final model has a standardized factor loading value of 0.472–0.709, so it closes a sufficient criterion. A sufficient criterion also obtained the CR with the instrumental factor of 0.77 and the relational factor of 0.71. Based on these two criteria, each factor has adequate convergent validity while the AVE value < 0.5. The discriminant validity was also adequate because the AVE value was greater than the values of MSV and ASV.

Reliability of BT-M

Analysis of each of the items showed that the coefficient of CITC (i.e. 0.373–0.584) exceeds the recommended criteria. The coefficient alpha estimates of internal consistency for the two factors were 0.715 and 0.761 for the instrumental and relational factors, respectively.

Beliefs about Assessment in Mathematics Learning (BA-M)

EFA of BA-M

The analysis was followed by PCA. There are two factors that had eigenvalues greater than one; two to three factors were recommended by the screen plot. The analysis was followed by establishing two factors that were rotated using the varimax and promax methods. Based on the results of each method of rotation, the varimax method generates many overlapping variables; whereas for promax, only one variable overlapped. Therefore, we used the promax method to set the number of factors and to remove one variable of overlapping (i.e. item 7) to perform the analysis. The solution was calculated from 50.166% of the total variance; 14 items that were used to describe both factors. Each of the items had a significant factor loading. We named each factor based on the relationships between the items that were associated with the relevant literature (Cooper, 1993; Jonassen, 1991; Pellegrino, Chudowsky, & Glaser, 2001; Purnomo, 2015, 2016; Shepard, 2000). Factor 1 was related to a view of assessment as an integral part of mathematics learning (abbreviated to integrated) and factor 2 to the assessment view that is irrelevant with the learning of mathematics (abbreviated to isolated). The alpha coefficient estimates of internal consistency were 0.828 for the integrated factor and 0.743 for the isolated factor.

CFA of BA-M

CFA by the ML method with Bollen-Stine bootstrapping was carried out with two-time improvement; the outputs obtained for the final model were $\chi^2(27) = 47.392$; p = 0.120; NC = 1.755; RMSEA = 0.049; SRMR = 0.037; GFI = 0.971; AGFI = 0.940; NFI = 0.954; TLI = 0.966 and CFI = 0.979. In other words, the index showed that the model had a good fit. A summary of the analysis is shown in Table 4.

Table 4. Fit Indices and BA-M Model Comparison

	Good fit	Acceptable fit	Model 0	Model 1	Model 2
NC	$1 \leq NC \leq 2$	$2 \leq NC \leq 3$	5,140	4,557	1,755
RMSEA	≤ 0.05	0.05 < RMSEA ≤ 0.08	0.114	0.106	0.049
SRMR	≤ 0.05	0.05 < SRMR ≤ 0.08	0.075	0.062	0.037
GFI	≥ 0.95	≥ 0.90	0.853	0.916	0.971
AGFI	≥ 0.95	≥ 0.90	0.796	0.865	0.940
NFI	≥ 0.95	≥ 0.90	0.768	0.850	0.954
CFI	≥ 0.95	≥ 0.90	0.763	0.838	0.966

TLI	≥ 0.95	≥ 0.90	0.802	0.878	0.979

Note:
Model 1: removal items isolated15, integrated9, integrated6, and integrated2
Model 2: pairs e13 and e9; e5 and e3; e10 and e9; e3 and e1; e11 and e12; e5 and e1 used free parameters

Construct Validity of the BA-M

Based on the values of standardized factor loading that were in the range of 0.532–0.792, each variable had an adequate factor loading. The CR values of the integrated and isolated factors were above the recommended threshold: 0.82 and 0.80, respectively. This indicated that convergent validity was quite adequate, although the AVE coefficient was less than 0.5. Furthermore, comparison of the values of AVE, ASV, and MSV shows that the AVE values were greater than the values of the other two; each factor had adequate discriminant validity.

Reliability of BA-M

Analysis of each item showed that the values of CITC are greater than 0.3, i.e. greater than the recommended threshold for item validity. Internal consistency indicated at the level sufficient in each factor with the values of 0.782 for the integrated factor and 0.773 for the isolated factor.

DISCUSSION AND CONCLUSION

We have reported on the development and validation of a scale to measure teachers' beliefs related to mathematics. Three subscales were analyzed separately, including teacher beliefs about the nature of mathematics, mathematics teaching, and assessment in mathematics learning. Based on the results of EFA, each subscale produced two factors. Beliefs about the nature mathematics produced dynamic and relevant factors. The dynamic factor is closely associated with the constructivist perspective of mathematics as a product of human thinking, continuously open for improvement, not a finished product, and having no absolute truth (Ernest, 1991, 1998; Hersh, 1997). Similarly, the relevant factor was also associated with the constructivist view that sees mathematics as an integral part of the nature of human thought, human culture, so it cannot be separated by physical science, nor the other sciences. Therefore, to describe the traditional beliefs about the nature of mathematics using this instrument, the data of one factor can be reversed. Similar scale factor can also be found in Op't Eynde and De Corte (2003) who developed the mathematics-related beliefs scale for students. In their study, the beliefs about traditional mathematics is measured by reversing the score obtained by a constructivism factor. Furthermore, beliefs about mathematics teaching and assessment in mathematics learning, each consisting of two factors together, can be associated with the view of constructivism and objectivism (Cooper, 1993; Jonassen, 1991).

Based on the results of the CFA, the suitability criteria for each scale at the limits were adequate. There were nine items of beliefs about the nature of mathematics, 11 items of beliefs of mathematics teaching, and 10 items of beliefs about assessment in mathematics learning. All subscales had adequate construct validity. The alpha coefficients were within 0.715–0.787, whose factors in each subscale had adequate internal consistency.

There were limitations, including only taking samples from primary school teachers in Jakarta. Therefore, further research needs to take samples from different populations (both in location and school level) to improve the generalization of the findings. In addition, assessed validity of the scales is only convergent and discriminant validity. Therefore, subsequent studies need to consider validity of others, such as divergent validity, predictive, etc.

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