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Validity and Reliability of The Instrument Using Exploratory Factor Analysis and Cronbach's alpha

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Abstract
The study was conducted to produce empirical data on the reliability and validity of the Teaching Framework for Mathematics (TF@Maths) questionnaire. A survey was conducted in one public university and one institution of teacher education in Northern Zone of Malaysia towards 436 students from the Mathematics Education. The reliability and validity of the TF@Maths questionnaire were tested with the Cronbach's alpha and Exploratory Factor Analysis (EFA) respectively using the Statistical Package for the Social Sciences (SPSS) software version 23. The TF@Maths questionnaire is a 7 point Likert- scale survey consisted of 86 items. The Cronbach's alpha test conducted shows that the overall score was 0.939 indicating high reliability of the items in the instrument. For validity, EFA was then conducted with the items using principal component analysis extraction and Varimax rotation. There were 62 items retaining with the factor loadings that was above 0.4. The factor analysis shows that the TF@Maths produced six factors, namely: mathematics content knowledge, mathematical pedagogical knowledge, general pedagogical knowledge, classroom management skill, mathematics disposition and quality mathematics teacher. The findings of TF@Maths will bebefit educational practitioners in designing a Teaching Mathematics Framework.
Keywords: Validity, Reliability, Exploratory Factor Analysis, Cronbach's Alpha, TF@Maths

Introduction

Although the validity and reliability are two different criteria, but both of them are intertwined in determining the quality of a research. Generally, reliability in quantitative research refers to two situations (i) the consistency of a measure; despite repeated several times and (ii) a measure of stability at all times (Kirk & Miller, 1986). The reliability of the measurement procedures can be defined as a measure of stability or consistency. Cronbach's alpha is used to obtain the reliability index of the instruments. The reliability index range is between zero ($\alpha=0$) to one ($\alpha=1$). High alpha value means higher reliability. According to

Pallant (2000), the index alpha of .7 or above is good for instruments that have ten or more items.

Meanwhile, validity refers to the extent to which an empirical measure effectively tested the real meaning of concepts under consideration (Babbie, 1990). According Fraenkel and Wallen (1996) in Ghazali & Sufean (2016), validity define as an appropriateness, truthfulness, meaningfulness and usefulness instrument that allows data to be inference. This study uses analysis Exploratory Factor Analysis (EFA) in determining the validity of the instrument. EFA, was conducted to identify and organize a large number of items of the questionnaire into the constructs under one specific variables (Chua, 2014). As suggested by Hair, Black, & Babin, (2010), EFA was to be conducted to determine a structure of latent dimensions among the observed variables reflected in the items of an instrument. Therefore, this study was undertaken to produce empirical evidence of the validity and reliability of the TLF@Maths questionnaire using Exploratory Factor Analysis and Cronbach's alpha.

Methodology of The Study

Sample and Data Collection

This study was a survey research. The researcher conducted this study in February and March 2017 involved of 436 respondents from a public university and institution of teacher education in Northern Zone of Malaysia. The respondents are studying Bachelor of Mathematics in Education. Prior to conduct this study was obtained permission from the lecturer to enter the classes. Next, the researcher introduced herself and explaining the purpose of the study before the consent letter and questionnaire were distributed. Then, each respondent was asked to read the instructions before answering the questionnaire and answer individually according to their own opinion without the help of other students. The respondents given time for about 30 minutes to complete the questionnaire. Finally, the questionnaire was collected and proceeding to data analysis.

Instrument

An instrument is used to measure the variables in the study. To serve as the effective data collection tool, questionnaire needs to be designed properly, particularly when the response rate as well as the reliability and validate of the data is affected by the design of questionnaires. Many aspects were considered in designing questionnaire including the choices of works, the sequence of the questions and the appearances (Zuraidah, 2014). A short and simple language that is easily understandable by all the respondents are used in order to encourage the respondents' cooperation and involvement throughout the questionnaire.

The questionnaire of this research begins with a cover letter to inform the respondents of the research purpose, assurance of the confidential of the feedback. Two parts in questionnaire for mathematics pre-service teachers, Part A and Part B. Part A is about respondents demographic and Part B is about the construct of the study. In Part A consists of six questions requiring the respondents to provide their background information on the semester, gender, age, ethnic, education level and programme are pursuing in the institution.

There are six domains in Part B that contains the total of 86 items which covers five related constructs of independent variables and one construct of dependent variable on quality mathematics teacher.

Table 1
Construct *of teaching and learning components for mathematics pre-service teacher.*

Construct	Domain	Number of item	Adapted
1	Mathematics Content Knowledge	10 items	MATHTED & SEI (2011) SET@MATHS (2009)
2	Mathematical Pedagogical Knowledge	24 items	MATHTED & SEI (2011) SET@MATHS (2009)
3	General Pedagogical Knowledge	11 items	MATHTED & SEI (2011); SET@MATHS (2009)
4	Classroom Management Skills	18 items	MATHTED & SEI (2011); SET@MATHS (2009)
5	Professional Development	14 items	MATHTED & SEI, 2011 SET@MATHS (2009)
6	Quality Mathematics Teacher	9 items	MATHTED & SEI (2011)

In order to obtain the true evaluation, the use of right number of point on a rating scale is critical. However, prior to decide the ideal number of scale points, the issue that need to be addressed was whether to employ a midpoint on scale or not. That is, to decide on whether to use the even or odd number on the rating scale. Though omission of the midpoint in a scale can increase the response precision, in contrast, it has been argued that the use of even-numbered scale may lead the respondents to biasness as they are forced to make a definite choice and increase tendency of respondents to respond negatively (Gwinner, 2006).

As such, the odd-numbered scale was applied to measure the respondents' view for this research. A seven-point Likert scale was used for the respondents. The questions had Likert responses of Not at all important (1), Low important (2), Slightly important (3), Neutral (4), Moderate important (5), Very important (6) and Extremely important (7) (Vagias, 2006). These responses ae assign values of one to seven, respectively.

Data Analysis

Factor Analysis: Exploratory Factor Analysis (EFA) and Cronbach's Alpha were used to examine the data in this study as shown in Table 2

Table 2
Summary of Data Analysis Methods

Purpose	Statistical Measures Used
Construct Validity	Factor Analysis: Exploratory Factor Analysis
Reliability	Cronbach's Alpha

The data were analyzed using Social Sciences (SPSS) software version 23. For factor analysis, items on the survey that did not exceed a 0.4 factor loadings cut off were deleted. Cross-loaded statements also were deleted. Only factors with eigenvalues greater than 1 were extracted and retained.

EXPLORATORY FACTOR ANALYSIS

Prior to performing the analysis, the researcher was examined for the accuracy of data entry, missing values, normality, and outliers. Skewness and kurtosis coefficients were also reviewed. In this study, all items were reasonably normally distributed, where the examination of the skewness and kurtosis statistics indicated that all values were within the range of ±2 (Garson, 2012). Meanwhile, the standard scores z for every item were in the range of ±4, showed no extreme cases and indicated that no outliers in the data. Therefore, the data were suitable for further analysis as no significant violation was found.

There were three aspects that needed to be looked into to determine the appropriateness of the data for factor analysis. The three aspects were sample size, factorability of the correlation matrix and the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy or Bartlett's Test of Sphericity. For sample size, Hair et al. (2010) suggested that sample sizes should be just 100 or larger. Tabachnick and Fidell (2007)suggested having at least 300 cases required for factor analysis. Chua (2014) and MacCallum, Widaman, Zhang, & Hong (1999)suggested that the number of sample sizes should be the greater of 5 times the number of variables. Thus, the sample size for conducting the EFA in this study must not less than 430 respondents (86 items times 5). Based on these arguments about determining the suitability of sample size for factor analysis, thus a sample size of 436 respondents was involved in this study.

For measure of sampling adequacy or whether data could factor well, Hair et al., 2010; Pallant, 2007; Tabachnick & Fidell, 2007 suggested that if the Kaiser-Meyer-Olkin (KMO) is greater than 0.6 and the Bartlett's Test of Sphericity (BTS) must be significant at $\alpha < .05$ then factorability of the correlation matrix is assumed. In other words, the KMO test and BTS determines whether the sampling was adequate to proceed with factor analysis (Maat, Zakaria, Nordin, & Meerah, 2011). In addition, a few steps need to be taken into the account by the researcher was the anti-image correlation for all items must above 0.5, the acceptable level (Coakes, Steed, Coakes, & Steed, 2003; Hair et al., 2010). Besides, the results provided for all items had a communality that was above 0.3 (Tabachnick & Fidell, 2007). The correspondence index for Exploratory Factor Analysis are shown in Table 3.

Table 3
Correspondence Index for Exploratory Factor Analysis

Indicators	Cut-off Value	Source
Kaiser–Meyer–Olkin (KMO) Meritorious: ≥0.80, Middling: ≥0.70,	Recommended value of 0.6 or above	Hair et al. (2010)

Mediocre: ≥0.60, Miserable: ≥0.50, Unacceptable: <0.50		
Bartlett's Test of Sphericity	Significant at $\alpha < .05$	Hair et al. (2010)
Anti-Image Correlation: individual measure of sampling adequacy (MSA)	> 0.5	Coakes & Steed, (2003); Hair et al., (2010)
Communalities (variables are well defined by the solution—low values require removal)	> 0.3 > 0.4 > 0.5	Tabachnick & Fidell (2007); Gaskin (2012); Hair et al. (2010)
Factor loadings Significant Factor Loading based on Sample Size	Above sufficient factor loading to retain the item while below sufficient factor loading to eliminate the item.	Hair et al. (2010)

Findings of The Study

Results from the reliability analysis presented in Table 4 indicated that the overall mean score, standard deviation and Cronbach's alpha were 6.1850, 0.46688 and 0.939 respectively before conducting the EFA. All of the Cronbach's alpha for the six constructs (86 items) were above 0.8, ranging from 0.857 to 0.929.

Table 4
Value Mean, Standard Deviation and Reliability for Each Construct.

Construct	Mean	Standard Deviation	Reliability
Mathematics content knowledge	5.9144	0.57026	0.800
Mathematical pedagogical knowledge	5.8952	0.52703	0.905
General pedagogical knowledge	6.0612	0.53852	0.837
Classroom management skill	5.7748	0.59298	0.872
Mathematic Disposition and Professional development	6.0577	0.55240	0.862
Quality mathematics teacher	6.3547	0.52811	0.872
Total	6.0097	0.45339	0.963

Exploratory Factor Analysis was started by conducting Kaiser-Meyer-Olkin Measure and Bartlett's test of sphericity of Sampling Adequacy Test on a set of 86 item's instrument. The appropriateness of factor analysis was supported by Bartlett's test of sphericity, an indicator of the strength of relationship among variables. It was found the results are significant ($\chi2$ = 20992.294). The KMO measure of sampling adequacy yielded a value of 0.960, indicating that the sample size was large enough to assess the factor structure. The procedures generated Kaiser–Meyer–Olkin value for each construct which was above 0.6 with a significant Bartlett's test of sphericity value, indicating that the data were sufficient to proceed for the factor analysis (Huck, 2012; Pallant, 2007; Tabachnick & Fidell, 2007). Finally, the communalities were determined for each item. The communalities of the items were range from 0.497 to 0.763 The Table 5 was shown the KMO, Communalities and Bartlett's Test results.

Table 5
Kaiser-Meyer-Olkin and Bartlett's Test

Test	Result
Bartlett's Test of Sphericity Approx. Chi-Square ($\chi2$)	20992.294
Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy	0.960
df	3655
Sig.	0.00
Communalities (Range)	0.497 to 0.763

Given these overall indicators, EFA was then conducted with 86 items using principal component analysis extraction and Varimax rotation. The minimum factor loading cut off point this study was 0.4. The six factors explaining 50.465 percent of the variance as shown in Table 6. The eigenvalues showed that the first factor explained 34.299 percent of the variance, the second factor 4.944 percent of the variance, the third factor 3.519 percent of the variance and the forth factor 2.913 percent. The fifth and sixth factors had eigenvalues of over one, each factor explaining about 2.518 percent and 2.273 percent respectively. Percentage variance in Extraction Sums of Squared Loading and Rotation Sums of Squared Loadings are the same, which explaining 50.465 percent. Varimax rotation has resulted the percentage of variance for factor 1 has been changed from 34.299 percent to 12.383 percent, percentage of variance for factor 2 has been changed from 4.944 percent to 10.682 percent, percentage of variance for factor 3 has been changed from 3.519 percent to 9.929 percent, percentage of variance for factor 4 has been changed from 2.913 percent to 7.217 percent, while percentage of variance for factor 5 and 6 have been changed from 2.518 percent to 5.543 and 2.273 percent to 4.711 percent.

Table 6
Summary of Total Variance Explained in Exploratory Factor Analysisi (EFA)

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %

1	21.265	34.299	34.299	21.265	34.299	34.299	7.678	12.383	12.383
2	3.065	4.944	39.243	3.065	4.944	39.243	6.623	10.682	23.065
3	2.182	3.519	42.762	2.182	3.519	42.762	6.156	9.929	32.994
4	1.806	2.913	45.675	1.806	2.913	45.675	4.475	7.217	40.212
5	1.561	2.518	48.192	1.561	2.518	48.192	3.436	5.543	45.754
6	1.409	2.273	50.465	1.409	2.273	50.465	2.921	4.711	50.465

Extraction method: Principal Component Analysis

Based on the Rotated Component Matrix, a total of twenty-four items were eliminated because twenty-three items failed to meet minimum factor loading of 0.4 or above and did not contribute to a simple factor structure. One item was discarded as its produced cross loaded item. As a result, there are a total of 62 items retained. The factor analysis results have showed that the TF@Maths produced six factors. The final items for generating TF@Maths with factor loading are shown in Table 7.

Table 7
Factor Loadings based on a principal component analysis extraction with Varimax rotation.

Item	Component					
	1	2	3	4	5	6
36	.614					
47	.597					
48	.597					
49	.565					
35	.555					
41	.554					
58	.546					
46	.535					
29	.524					
37	.523					
38	.471					
40	.466					
25	.465					
32	.463					
34	.461					
55	.458					
50	.455					
44	.453					
23	.436					
84		.710				
79		.701				
85		.659				
81		.649				

Item	Component					
	1	2	3	4	5	6
78		.641				
80		.613				
86		.598				
82		.593				
83		.578				
69		.540				
51		.489				
22		.448				
56			.680			
52			.625			
54			.616			
59			.602			
60			.580			
31			.543			
57			.534			
67			.494			
16			.492			
26			.468			
53			.460			
68			.437			
11				.673		
12				.666		
17				.637		
13				.602		
14				.493		
21				.468		
15				.464		
18				.462		
20				.431		
3					.697	
2					.691	
4					.621	
5					.617	
1					.612	
71						.622
72						.533
73						.514
76						.469
77						.464

Based on the result of EFA, there were nineteen items that loaded onto Factor 1 measure teachers' understanding and use of teaching approaches in general contexts. This was labelled, "General Pedagogical Knowledge" (GPK). There were twelve items in Factor 2 all relate to the quality of teaching mathematics. This factor was labelled, "Quality

Mathematics Teacher" (QMT)". Twelve items loaded onto Factor 3 and were related to teachers' approaches in providing for the favourable learning environment. This factor was labelled, "Classroom Management Skills (CMS)." The nine items that loaded onto Factor 4 relate to teachers' understanding and use of teaching approaches, learning theories and modalities particular to mathematics. This factor was labelled, "Mathematical Pedagogical Knowledge (MPK)". Five items loaded onto Factor 5 is related to teachers' knowledge of, understanding of and competencies in the contents of mathematics. This was labelled, "Mathematics Content Knowledge (MCK)". For Factor 6, the five items relate to teachers' belief and attitude, their inclination to use mathematics and their willingness to reach out to others. This factor was labelled, "Mathematical Disposition" (MDP). (Table 8)

Table 8
The Different Number of Pooled Item for Each Construct after Exploratory Factor Analysis

Factor	construct	List of Old Item	List of New Item
1	General Pedagogical Knowledge	11	19
2	Quality Mathematics Teacher	9	12
3	Classroom Management Skills	18	12
4	Mathematical Pedagogical Knowledge	24	9
5	Mathematics Content Knowledge	10	5
6	Mathematical Disposition	14	5

Conclusion
Exploratory Factor Analysis results has demonstrated that there are six main factors in generating teaching framework for mathematics. The six constructs are mathematics content knowledge, mathematical pedagogical knowledge, general pedagogical knowledge, classroom management skill, professional development and quality teaching in mathematics.

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