BEST: International Journal of Humanities, Arts, Medicine and Sciences (BEST: IJHAMS)
ISSN (P): 2348–0521, ISSN (E): 2454–4728
Vol. 8, Issue 12, Dec 2020, 23-32

DEVELOPMENT AND VALIDATION OF MATHEMATICSTEACHING PRACTICES SCALE

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ABSTRACT

The present study describes the development and validation process of the Mathematics Teaching Practices Scale (MTPS). The MTPS is an instrument developed and validated based on Philippine context to measure the mathematics teaching practices of Filipino mathematics teachers. 786 valid responses of secondary mathematics teachers were randomly divided into two subsamples and were used separately for exploratory and confirmatory factor analysis. Test of significance of the two subsamples revealed that the subsamples are equivalent based on the participants' age and sex. An exploratory factor analysis of 393 participants suggested a 22-item scale that is subdivided into five factors. A confirmatory factor analysis of the 393 participants suggested modifying the structural model of the MTPS which resulted to the shortened number of items in the final scale. The validity and reliability tests revealed that the MTPS is valid and reliable instrument to use for its intended purpose.

KEYWORDS: Exploratory factor analysis, confirmatory factor analysis, Mathematics teaching practices, Scale development, Validity & Reliability

INTRODUCTION

Modern mathematics classrooms and new generation students require mathematics teachers that have a strong mastery of mathematics as a subject matter (Elipane, 2012). Lomibao (2016) noted that the most important ingredient in improving students' learning outcome in enhancing teachers' quality. Further, Lomibao (2016) claimed that "the efficiency and effectiveness of the learning experience is dependent on the teacher quality."

Thus, this suggests that teachers must have not only wide knowledge about mathematics, but also deep understanding about every subject matter. SEI-DOST and MATHTED (2011) argued that having deep understanding about mathematics does not make one an effective mathematics teacher at all. He/she must also have deeper understanding on how to teach mathematics.

Mathematics teaching practices or mathematics teachers' instructional practices refer to what actually happen inside the classroom (Depaepe & Konig, 2018). Since teaching nowadays does not occur only inside the classroom, mathematics teaching practices can be viewed as what the teacher actually do to make mathematics teaching meaningful to learners.

According to Ball and Forzani (2010), responsible instructional practice means working tirelessly to make all students: (1) solve problems related to local, national and global issues; (2) use and adapt to rapidly changing technology; (3) interact effectively to global society. It is the product also of responsible instructional practice to minimize educational inequities (Ball & Forzani, 2011).

Teaching mathematics is not an easy task. It requires mathematics teachers a variety of skills necessary to produce student achievement. More specifically, teachers must possess mathematical content knowledge, as well as ability to translate that knowledge into effective teaching practices to promote student learning (Hill, Rowan, & Ball, 2005). Shulman (1986) categorized a type of knowledge that deals about teaching. He calls this type of knowledge as Pedagogical Content Knowledge (PCK) (Hill, Rowan, & Ball, 2005). Possessing higher order of mathematical content knowledge is as equally important as having the skills and abilities to translate that knowledge into effective mathematics teaching practices (SEI-DOST & MATHTED, 2011).

Across national organizations in the world, researchers have identified the importance of mathematics teaching practices for students' experiences towards mathematics learning (Boaler, 2002; Borko et al., 2005; Wolkawiak et al., 2014). These mathematics teaching practices were categorized by Borko and her colleagues into eight (8) dimensions, namely: (1) Structure of the lesson; (2) Multiple representations; (3) Students' use of mathematical tools; (4) Cognitive demand; (5) Mathematical discourse community; (6) Explanation and justification; (7) Problem solving; and, (8) Connections and applications (Borko, Stecher, & Alonzo, 2005). These eight (8) dimensions of mathematics teaching practices have been the basis for developing Mathematics Scan (M-Scan), a scale that measures standards-based mathematics teaching practices (Wolkawiak, Berry, Meyer, Rimm-Kaufman, & Ottmar, 2014).

In the Philippines, mathematics teachers are guided by two set of professional standards, the Framework for Philippine Mathematics Teacher Education (FPMTE) and the Philippine Professional Standards for Teachers (PPST). The former was developed by the Science Education Institute – Department of Science and Technology (SEI-DOST) and Philippine Council for Mathematics Teacher Education (MATHED), while the latter was the introduced by the Department of Education (DepEd).

The Framework for Philippine Mathematics Teacher Education (FPMTE) is a guide for Filipino mathematics teachers on how to become an effective mathematics teacher. The framework contains knowledge descriptions and performance indicators of the qualities of effective mathematics teachers in terms of what they should know (content knowledge), what they are expected to do to achieve quality learning outcomes (pedagogical knowledge) and what they should possess to be able to manage the different aspects of the teaching and learning process (management skills). MATHED coined the term Mathematical Pedagogical Knowledge (MPK) to the knowledge about teaching mathematics. However, MATHED also emphasized that mathematics teachers must also have deep understanding about the general pedagogical knowledge and management skills (SEI-DOST & MATHTED, 2011).

There are four domains of the mathematical pedagogical knowledge (MPK) introduced in the FPMTE namely: (1) Knowledge of school mathematics; (2) Knowledge of students' cognition of mathematics; (3) Knowledge of tasks of mathematics teaching; and, (4) Knowledge of mathematical discourse (SEI-DOST & MATHTED, 2011, pp. 27-29).

The general pedagogical knowledge and management skills of teachers found in the FPMTE are also categorized into four domains, namely: (1) Knowledge of Students, their Cognitive Development and Contexts; (2) Knowledge of General Teaching Techniques and Classroom Processes; (3) Knowledge of Theories of Assessment; (4) Knowledge of Professional responsibilities (SEI-DOST & MATHTED, 2011).

The Philippine Department of Education (DepEd) through DepEd Order No. 42, s. 2017, issued a policy on national adoption and implementation of the Philippine Professional Standards for Teachers (PPST). The PPST establishes what is meant by teacher quality in the K to 12 Reform through well-defined domains, strands, and indicators that provide measures of professional learning, competent practice, and effective engagement. This set of standards makes explicit what teachers should know, be able to do and value to achieve competence, improved student learning outcomes, and eventually quality education. It is founded on teaching philosophies of learner-centeredness, lifelong learning, and inclusivity/inclusiveness, among others (DepEd Order No. 42, 2017).

The PPST is composed of seven domains which are collectively comprised of 37 strands that refer to more specific dimensions of teacher practices (DepEd Order No. 42, 2017). Of the seven domains, five refer to specific teaching practices that are observable in the actual classroom setting are as follow: (1) Content Knowledge and Pedagogy; (2) Learning Environment; (3) Diversity of Learners; (4) Curriculum and Planning; and, (5) Assessment and Reporting.

In view of the abovementioned domains from M-Scan, FPMTE and PPST, the researcher has developed a scale that will measure the mathematics teaching practices expected to be present in every mathematics classroom.

There were already readily available international scales in the market that measures the mathematics teaching practices of teachers, however these scales were not tested to Filipino teachers and in Philippine setting. The proposed scale has been developed, pilot-tested and validated for Filipino teachers and in the Philippine setting. With the proposed scale being tested to Filipino teachers, it will cater to measure the mathematics teaching practices of Filipino mathematics teachers.

MATERIALS AND METHODS

A. Development of Items

The first step in scale development was defining the construct needed to be measured (Worthington & Whittaker, 2006). Since the present study was interested on measuring the mathematics teaching practices of teachers, the instrument developed was intended to measure the construct mathematics teaching practices.

Based from this construct the researcher generated a pool of items by adapting indicators and statements from (1) Mathematics Scan (M-Scan) developed by Wolkawiak, et al. (2014); (2) Philippine Professional Standards for Teachers (PPST) introduced by the Department of Education (DepEd); and, (3) Framework for Philippine Mathematics Teacher Education (FPMTE) introduced by the Science Education Institute-Department of Science and Technology (SEI-DOST) and Philippine Council for Mathematics Teacher Education (MATHED) (SEI-DOST & MATHTED, 2011).

The M-Scan was an observational scale that measures standards-based mathematics teaching practices by assessing use of mathematical tasks, mathematical discourse, mathematical representations and mathematical coherence (Wolkawiak, Berry, Meyer, Rimm-Kaufman, & Ottmar, 2014).

The PPST or Philippine Professional Standards for Teachers was a clear set of standards that explained what teachers should know, be able to do and value to achieve competence, improve student learning outcomes, and eventually quality education (DepEd Order No. 42, 2017).

The FPMTE or Framework for Philippine Mathematics Teacher Education contained resources that could guide higher education institutions, professional organizations of mathematics teachers and school administrators in assessing and improving the performance and career development of mathematics teachers based on a set of standards (SEI-DOST & MATHED, 2011).

There were 14 statements adapted from the FPMTE, 13 from PPST and 11 from M-Scan. There were 38 items in the initial draft of the scale. The scale was named as Mathematics Teaching Practices Scale or MTPS.

A content validity was conducted by the experts from different institution who were teaching mathematics. Eight (8) experts were commissioned to validate the content of the MTPS as to its relevance to the construct mathematics teaching practices. Of the eight (8) experts who validated the content of the scale, three (3) were public secondary school teachers and five (5) came from state universities. The five (5) experts from state universities were teaching also at secondary students in the Laboratory Schools as well as college students in their respective universities. As noted by Lynn (1986) a minimum of three (3) experts was required for content validity however, more than ten (10) was unnecessary.

After the content validity, six (6) statements adapted from FPMTE and two (2) statements adapted from M-Scan were discarded. Only 30 items retained. The eight (8) items that were discarded did not meet the required item-level content validity index (I-CVI). Lynn (1986) developed a criterion for item acceptability. She recommended that for six or more judges, an item is accepted if it is not lower than 0.78. In the case of MTPS, eight (8) items fall short of the recommended I-CVI, thus these items were discarded. The I-CVI of the 30 items being retained ranged from 0.875 to 1.00. The item such as *"Most of the activities of the lesson are open-ended requiring answers not found on the book."* and *"Students engage in problems that allow them to grapple with mathematical concepts."* were discarded.

From the 30 items being retained four (4) were recommended to be revised based on the suggestions of the experts. These four (4) items were marked with I-CVI of 0.875. One item that was suggested to be revised was item 13 which states, *"Students are asked to apply the math they learn to the world around them."* This item was revised into *"The activities of the lesson will engage students to use and apply mathematical content knowledge not only within the subject but also across other field of disciplines."*

The overall content validity index or scale-level CVI (S-CVI) of the MTPS is 0.95. Waltz, Strickland and Lenz (2005) suggested that an acceptable scale should have at least 0.90 S-CVI. The MTPS with its S-CVI of 0.95 is therefore acceptable and content valid.

After the revision of the four (4) items, the final scale was prepared and had undergone final content validity. The experts accepted the revision made by the researcher on the items recommended for revision. The I-CVI of the new scale ranges from 0.875 to 1.00. The final S-CVI of the scale is 0.96 which is at acceptable level and hence, content valid.

The MTPS adapted a 5-point scale on which a "1" represented "never" and a "5" represented "always," to indicate to what extent each item or mathematics teaching practices is observed in their mathematics classes.

B. Participants

The study was carried out with a sample of 786 secondary junior high school mathematics teachers from 33 schools division offices (SDO) in the Philippine Department of Education (DepEd). Of the 33 SDOs, 20 were city schools divisions while 13 were provincial schools divisions. Using the stratified random sampling technique, the participant schools and teachers were selected. The mean age of teacher-participants was 36 years with a standard deviation of 10 years. The participants' ages were ranging from 20 to 60 years. The distribution of the educational level of the teacher-participants is shown on Table 1. The 786 participants are composed of 78 per cent females and 22 per cent males.

C. Procedure

A request letter seeking approval to administer the MTPS for pilot testing to secondary mathematics teachers was sent to respective schools division superintendents in the DepEd. These superintendents endorsed the proposed scale to secondary mathematics teachers in their respective schools divisions. A sample of 786 secondary mathematics teachers participated in the validation process. The 786 responses will be randomly divided into two subsamples of equal number (n_1=393 and n_2=393). The first subsample will be used for exploratory factor analysis (EFA) while the second subsample will be used to validate the results obtained in the first subsample using the confirmatory factor analysis (CFA). Of the 786 responses, 605 were answers from the online Google form while the 181 were answers from the hard copy of the scale sent by the respective schools division superintendents.

Table 1: Educational Level of Participants

		N	%	% males	% females
Undergraduate	BSE Mathematics	749	95.29	21.63	73.66
	BSE Physical Science	3	0.38	0.38	-
	BS Mathematics	13	1.65	1.27	0.38
	BS Civil Engineering	13	1.65	1.27	0.38
	BS Computer Engineering	8	1.03	0.65	0.38
	TOTAL	786	100	25.20	74.80
Postgraduate	No master's degree	209	26.59	7.38	19.21
	With units in master's degree	369	46.95	8.15	38.80
	Candidate for master's degree	82	10.43	3.05	7.38
	Master's degree holder	125	15.14	3.69	11.45
	With units in doctorate degree	2	0.89	0.89	-
	TOTAL	**786**	**100**	**22.90**	**77.10**

Note**:** BSE=Bachelor of Secondary Education; BS=Bachelor of Science

RESULTS AND DISCUSSIONS

A. Exploratory Factor Analysis

The first subsample (n_1=393) was used perform the exploratory factor analysis (EFA) while the second subsample (n_2=393) was used as a validation for confirmatory factor analysis (CFA). Table 2 shows the test of significance of the two subsamples with respect to the participants' age and sex. The results show that there is no significant difference between the two subsamples with respect to the participants' age and sex. Thus, it can be concluded that the two subsamples are equivalent.

The adequacy of the sample to perform EFA was confirmed by the KMO Measure of Sampling Adequacy and the Bartlett's Test of Sphericity shown in Table 3. Hutcheson and Sofroniou (1999) considered values between .80 and .90 as *"great vales"* for KMO (Field, 2009).

A Principal Axis Factoring (PAF), with orthogonal rotation (varimax), factor analysis of the responses of 393 resulted in a rotated factor matrix that showed seven factors which had item loadings at 0.40 and above (see Appendix). Worthington and Whittaker (2006) suggested the use of principal axis factoring for new scale development.

Table 2: Test of Significance of the Two Subsamples with respect to Sex and Age

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% CI of the Difference	
									Lower	Upper
Sex	Equal variances assumed	2.580	.109	-.814	294	.416	-.041	.050	-.139	.058
	Equal variances not assumed			-.804	239.764	.422	-.041	.051	-.141	.059
Age	Equal variances assumed	.418	.519	.938	223	.349	1.350	1.439	-1.487	4.186
	Equal variances not assumed			.938	174.809	.352	1.350	1.446	-1.504	4.203

In determining the number of factors to be considered, the researcher observed a number of criteria: the Kaiser-Gutman rule, Cattell's scree-test and the parallel analysis. The Kaiser-Gutman rule and the parallel analysis suggested retaining the seven factors however the scree-test suggested only one factor. Upon close examination of the seven factors, two factors, factor six and seven had only two items in it that loaded. These two factors were immediately eliminated since the correlations of the respective items in factors six and seven are very low. The researcher decided to retain a five-factor solution as shown on Figure 1.

Table 3: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.888
Bartlett's Test of Sphericity	Approx. Chi-Square	1810.666
	df	435
	Sig.	.000

As seen on Appendix, only 26 items loaded on the seven factors with loadings of .40 and above. However, the two items for each of factor six and seven were eliminated. The final scale was made up of 22 items.

Seven items grouped to factor one. These items were dealing about teaching practices that focuses on classroom discourse. Thus, the researcher named factor one as "teaching Practices on Classroom Discourse." The five items that clustered on factor two are teaching practices about the use of mathematical tasks, and so, the researcher named it as "Teaching Practices on the Use of Mathematical Tasks." The three items that clustered on factor three are teaching practices about providing equal opportunities for learning. Thus, it was named as "Teaching Practices on Opportunities for Learning." Similarly, factor four was named as "Teaching Practices on Problem Posing" and factor five was named as "Teaching Practices on Differentiated Learning."

B. Confirmatory Factor Analysis

The structural validity of the Mathematics Teaching Practices Scale (MTPS) was determined through the CFA using the AMOS version 23 on the second subsample (n_2=393). The initial model of the MTPS included five latent variables which are the five factors of the MTPS – Classroom Talk, Mathematical Tasks, Opportunities for Learning, Problem Posing and

Differentiated Learning.

Model fit was assessed using absolute indices, such as Chi-square index (x^2) the root-mean-square-error-of-approximation (RMSEA) and the standardized root mean square residual (SRMR), as well as the incremental measures of fit particularly the comparative fit index (CFI) and the Tucker-Lewis index (TLI). Hu and Bentler (1999) explained that there is model-data fit if the Chi square value is nonsignificant, the RMSEA is .06 or less and the SRMR is .08 or less. They added that CFI and TLI of values of at least .95, indicating a good fit of model to the data provided. The initial model shown on Figure 1, showed poor fit as indicated by the fit indices.

The suggested modification in the AMOS analysis were considered in search of the new model that will best fit the data from the second subsample, such as elimination of the regression weights below .50. After several modifications, a new model presented on Figure 2 was considered as the best model that fits the data from the second subsample. The fit indices for the final model as well as the initial model are shown on Table 4 for comparison.

The Chi-square value of the initial model is significant at .001 while the final model is nonsignificant at .001 although it is significant at .05. The RMSEA of the initial model did not meet the threshold required while the final model met the required value. For the SRMR both values of the initial and final model met the criteria. However, the CFI and TLI of the initial model did not meet the required values. As for the final model it did meet the required values. Comparing the fit indices of the initial and final model of the structure of the MTPS shows that the final model best fit the data.

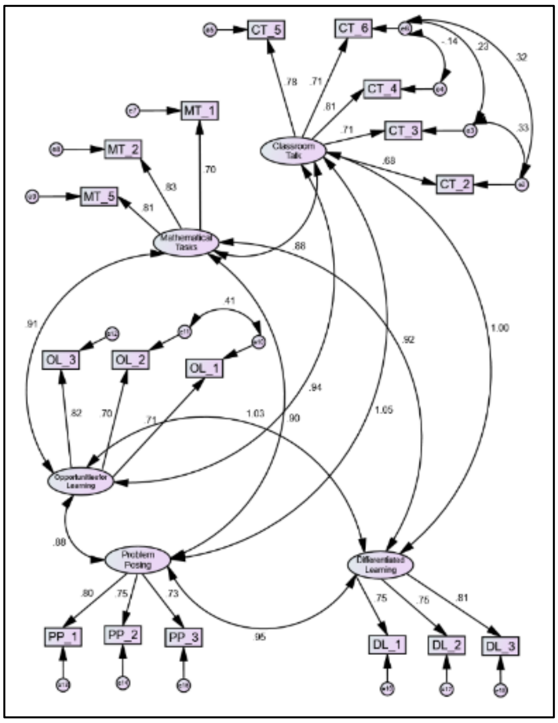

Figure 1: Initial Model of MTPS

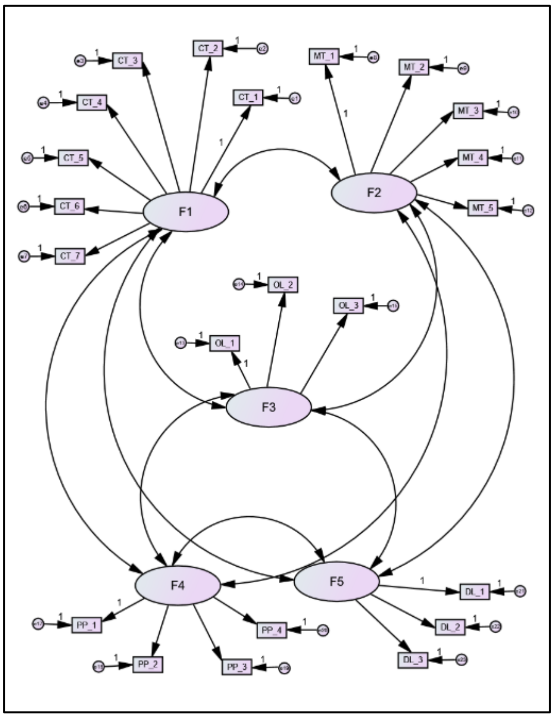

Figure 2: Final Model of MTPS

Table 4: Comparison of Fit Indices of Initial and Final Model of the Structure of MTPS

Fit Indices	Initial Model	Final Model
Chi-square index	310.633	136.721
p-value	.000	.017
RMSEA	.069 (.054 - .080)	.042 (.019 - .061)
SRMR	.022	.019

CFI	.89	.98

C. Evidence of Reliability and Validity

To check the reliability of the MTPS, the internal consistency (Cronbach's alpha) of the scale was computed. George and Mallery (2003) provided a rule of thumb for interpreting the computed Cronbach's alpha: α > .90 – Excellent; α > .80 – good; α > .70 – acceptable; α > .60 questionable; α > .50 – poor; α < .50 – unacceptable. The computed Cronbach's alpha of the MTPS was .94. This shows that the MTPS is of excellent reliability. Table 5 shows the internal consistency and the inter-item correlations of the five subscales of the MTPS. The computed Cronbach's alpha and inter-item correlations for all the subscales shows adequate values. This suggests that the MTPS is indeed of excellent reliability.

Table 5: Reliability: Internal Consistency Measures Results

Subscale	Cronbach's Alpha	Average Inter-Item Correlation
Classroom Talk	0.90	0.57
Use of Mathematical Tasks	0.84	0.51
Opportunities for Learning	0.83	0.62
Problem Posing	0.81	0.58
Differentiated Learning	0.81	0.59

The content validity of the MTPS was already established following the guidelines recommended by Lynn (1986) in determining the content validity. The structural validity of the MTPS, being one aspect of construct validity, was established through the confirmatory factor analysis (CFA). All items under each latent factor of the MTPS were found to be significant. The reduced number of items in the MTPS was the result of the several modifications made during the CFA. It is considered that the shortened scale is still desirable for the final scale since the purpose of the CFA is to develop a parsimonious scale (Stapleton, 1997). The results of the CFA indicate a valid and reliable instrument.

CONCLUSIONS

The goal of the present study is to develop a standardized instrument based on Philippine context and frameworks that will measure the teaching practices of Filipino mathematics teachers. Several teaching practices scale have already been developed in the international level, however these scales were not yet tested for Philippine context. According to Capuyan, Antonio and Orleans (2019), the structure of classroom talk in one Province in the Philippines is significantly different from those in Singapore. In a similar manner, by adapting an instrument that was tested and validated at a different context might provide a different result. Teaching practices scales developed at foreign countries might be significantly different as the what teaching practices it measures when used in the Philippine setting.

Mathematics teaching practices scales have been developed based on the current frameworks adapted in the Philippines with respect to mathematics teaching practices. Incorporating the components of standards-based mathematics teaching practices from a well-established scale in the foreign country will not harm the development of the teaching practices scale intended for the Filipino teachers.

Having been established its validity and reliability, the MTPS can now be used to measure the standards-based mathematics teaching practices in the secondary mathematics classes in the Philippines.

APPENDIX

Appendix A - Factor Loadings of Items

Statements	Factors						
	1	2	3	4	5	6	7
29. I ask questions that encourage students to deeper mathematical understanding.	.65						
28. When students provide explanations, it focuses on conceptual understanding of the topics.	.69				.41		
25. Student's provide explanations and/or justify their reasoning.	.63						
24. I use appropriate strategies to bring out students' ideas, questions and inputs.	.71						
26. I provide activities that lead students to discover mathematical concepts.	.80						
27. Students make connections between the mathematical tools to be used and the mathematical concept.	.76						
30. I and my students use multiple representations (graphs, pictures, symbols, words, etc.) to explain a mathematical concept.	.62						
1. The activities of the lesson will engage students to use and apply mathematical content knowledge not only within the subject but also across other field of disciplines.		.55					
4. I apply a wide variety of teaching strategies that enhance learner achievement in literacy and numeracy skills.		.67					
3. I ensure that students can select and use appropriate mathematical tools (protractor, ruler, calculator, etc.) to investigate and solve problems.		.59					
14. Throughout the math discussion, students consistently participate.		.54					
5. I apply a wide variety of teaching strategies to develop critical and creative thinking, as well as other higher order thinking skills.		.69					
11. I provide safe and secure learning environment to enhance learning.			.71				
12. I provide each student equal opportunity to learn.			.78				
13. I provide activities that engage learners, individually or in groups, in meaningful exploration, discovery and hands-on activities.			.75		.41		
21. I provide activities that make students formulate problems based on the concepts being discussed.				.75			
22. If students formulate problems, they must be solved with multiple strategies.				.77			
23. I provide activities that are relevant to students' lives.	.45			.64			
20. I encourage students to make conceptual connections.				.70		.48	
8. Classroom activities encourage multiple strategies to solve each problem.					.75		
9. I use appropriate strategies for providing timely, accurate and constructive feedback to improve learner performance.					.61		
16. I provide varied and appropriate learning experiences to address learner's gender, needs, strengths, interests and experiences.					.79		
19. I design, select, organize and use appropriate assessment strategies aligned to the learning outcomes set prior to the lesson.						.55	
18. I set achievable and appropriate learning outcomes that are aligned with learning competencies.	.44					.52	
2. I select and use appropriate ICT tools that will facilitate the teaching and learning process.							.51
7. I provide examples that allow students to think and decode the mathematical concepts being presented.					.42		.45

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