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Validation of a teacher mathematics knowledge scale based on the Ernest framework among Malaysian teachers

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ABSTRACT

The aim of the current research was to validate the Malaysian version of the mathematical knowledge scale based on the Ernest framework. The participants include 100 teachers from Kelantan, Malaysia. An exploratory factor analysis (EFA) with principal components analysis and varimax rotation was conducted. This research determines the number of factors through eigenvalues greater than one and frames the structure of the scale through factor loading. The value of the eigenvalue and factor loading are considered in this research to frame and develop the structure of the scale. Furthermore, the reliability of the scale was tested with Cronbach's alpha. The results showed six factors on the scale explaining 67.39% of the variances. A total of 26 items with factor loading greater than 0.60 were determined for the scale. The structure of the scale was as three items in the first factor, two items in the second factor, five items in the third factor, four items in the fourth factor, 10 items in the fifth factor, and two items in the sixth factor. Furthermore, the reliability of the scale was 0.958. This research concluded that the scale was internally consistent in measuring the teacher's mathematics knowledge.

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1. INTRODUCTION

Mathematical knowledge is important for students to master. According to Arseven [1], mathematics is the most common comprehension subject because it can be used in various areas, even those which are not related to the mathematics field. Mathematical knowledge consists of several skills, namely problem solving, reasoning, connecting and representing [2]. Therefore, according to Nadarajan *et al*. [3], students will face problems in reasoning, reflecting, making decisions, innovating, and creating something if they do not master mathematical knowledge. Hill *et al*. [4] stated that mathematics is the gatekeeper subject because it benefits the life span, improves employment chances, and informs choices about the environment, health, and wellbeing. The benefits of mathematic knowledge acquired through mathematics lead to logical thinking, daily life problem solving, recognizing patterns of relationships, developing creativity, and increasing awareness [5]. According to Szabó *et al*. [6], the main purpose of mathematics education is to enable students to solve their daily life problems. Mastering mathematics equips students with deep critical and analytical skills [7]. Several countries such as the United Kingdom, United State of America, Finland, and Australia believed that mathematical knowledge improved students thinking capacity as well as their critical, creative, and logical understanding of daily life situations [8]. The benefit of mathematic knowledge can be achieved when students are solving mathematic contextual problems that are related to their daily lives [9]. Therefore, mastering mathematics would be beneficial for the students.

Regarding the importance of mastering mathematical knowledge, Malaysian students were found to have a lower score in mathematics assessments. The scores of Malaysian students in Trends in International Mathematics and Science Study (TIMSS) and Program for International Student Assessment (PISA) were not at satisfactory level. Malaysia, in their first participation in TIMSS and PISA in 1999, obtained an above-average score with a mean score of 519, which put them ranked 16 out of 38 countries [10]. However, in the earlier test, Malaysian eighth graders in TIMSS showed declining trends. As stated by Yang and Sianturi [11], Malaysia was frequently ranked at the bottom in the TIMSS test. Hassan [12] also stated that the scores of Malaysian students in TIMSS and PISA were less than satisfactory. For example, in 2011, Malaysia ranked 26th out of 45 countries with a mean score of 440 [10]. This score improved in 2015 with an overall score of 465 [13]. However, this score decreased in 2018, with an overall score of 440 [14]. The low scores of Malaysian students in TIMSS and PISA indicate that their mastery of mathematical knowledge is low.

The minimum score of Malaysian students in TIMS and PISA might be related to teacher competency in mathematic teaching. Rohid *et al.* [7] stated that the effectiveness of mathematic learning in the classroom heavily depends on the teacher's ability to facilitate learning. Exactly, teachers hoped to generate an effective and suitable curriculum for mathematical teaching [1]. It is because teachers play an important role in determining the quality of education [15]. Sandt [16] stated that teachers are the ones who filter the curriculum, which makes them play a central role in bringing out the desired reform in education. In this case, according to Ernest [17], there are three important aspects of mathematical teaching, including teacher content knowledge, teacher belief, and teacher attitude. The model proposed by Ernest [17] could be an indicator of the success of mathematical education [18].

The Ernest model [17] emphasizes teacher mathematical content knowledge, which according to Rahman *et al.* [19] should be mastered by teachers to be qualified teachers. According to Wilkins [20], teachers' mathematical knowledge influences their efficacy and choice of instructional practices in the classroom. Sandt [16] further explains that mathematical content knowledge includes knowledge of how the student thinks and learns, knowledge of how the student acquires mathematic material, as well as knowledge related to the process of students understanding and difficulties. Yılmaz [8] stated that the aspect of math teacher knowledge is knowledge of curriculum and pedagogy, which is an important determinant of the instructional quality that could motivate the student`s development. It is argued that mathematic content knowledge is not solely related to mathematic content but also related to mathematic teaching. In this case, Gallagher *et al*. [21] stated that teachers should transform their mathematical teaching knowledge into a form that is pedagogical and adaptive to the variations based on the classroom conditions. The mathematical knowledge proposed by Ernest [17] is knowledge of mathematics, knowledge of the subject matter, knowledge of teaching mathematics, including pedagogical knowledge and curriculum knowledge, knowledge of classroom organization and management, including school context and school taught, and knowledge of education, including psychology and mathematics education. This has become the domain of Ernest [17] mathematical knowledge concept.

Research related to the knowledge of mathematics teachers based on the Ernest framework [17] is less widely known in the Malaysian context [22]. Eu *et al.* [23] conducted several studies with similar contexts to examine Malaysian preservice mathematic teachers' content and pedagogical knowledge. However, the research did not examine teacher classroom management understanding, student psychology, or teacher knowledge of the math curriculum. Abdullah *et al.* [24] identify the level of knowledge and practice of Malaysian mathematic teachers. This research has identified teacher knowledge in terms of curriculum, pedagogy, and assessment. However, the scale used was not validated. Furthermore, the lack of research in mathematical knowledge in Malaysia is proved by the fact that almost no standardized data about teacher math competences is available [25]. According to Scheiner *et al.* [26], scholars have recently addressed this issue by identifying the facet of math content knowledge; however, several scholars have pointed out the inadequacy of the conceptualization of math teacher knowledge [27]. Therefore, more research related to Malaysian teacher knowledge in math should be emphasized, specifically using the framework proposed by Ernest [17].

Based on the explanation, there is a need to examine the teacher's mathematical knowledge. Therefore, instrument measures the Malaysian teacher's mathematical knowledge should be provided. It is emphasized by Baier *et al*. [28] in their research that, in terms of teacher professional knowledge, the relevant aspect of teacher knowledge should be measured by standardized items. It means the valid and reliable item measuring the teacher's mathematical knowledge in the form of an instrument should be tested. However, the instrument specifically measuring the teacher's knowledge in Malaysian context was not provided in the literature. Exactly, there are several studies that have developed and validated scales to measure teacher math knowledge. For example, Durmuş and Bıçak [29] developed a scale to measure the mathematical value of preservice teachers. However, this scale is tested on turkey participants and does not specifically examine the teacher's mathematical teaching domain. Szabó *et al*. [6] develop a scale measuring opportunity to learn, belief and mathematic knowledge for teaching. However, this scale tested in American sample. Research by Aksu *et al*. [30] developed the pedagogical content knowledge scale for pre-service teachers. However, the scale does not specifically measure the teacher's mathematical knowledge. Dağlı *et al*. [31] developed a preschool teacher pedagogical content knowledge scale for mathematics. This research provides a specific scale to measure teacher mathematical knowledge; however, the scale is tested in Turkey and only examines teacher content knowledge. Other researchers who validated mathematic knowledge were [32], [33]. However, this research only focused on the teacher's mathematical knowledge and did not cover the teacher's mathematical teaching skills. Based on the explanation, a specific instrument to measure teachers' mathematic knowledge in Malaysian context is not provided yet. Therefore, the current research intends to validate the teacher's mathematical knowledge based on the framework [17].

Testing the appropriateness of an instrument in a specific sample is important. It is because the sample might have different cultural background, socio-economic condition, and situation. Other than that, a scale might be changed based on the time frame, which means that scale testing needs to be done from time to time to make sure that the scale is valid and reliable to be used based on the current situation in the sample location [34], [35]. Therefore, in the current research, the scale will be tested through factorial analysis to justify the appropriateness of the scale. This is because exploratory factor analysis (EFA) can identify and organize large number of questionnaire items into factors (or components) one-on-one. Which then produce the construction of the study sample that really represents the study variable [36]–[39]. This process requires the abortion of uncorrelated items to form single factors in a single survey question as a new interpretation of the new factors [36], [40]. In its process, EFA used to drop items from the scale based on the factor loading values and cross factors. Therefore, factor analysis will be used in this research to validate the instrument.

2. RESEARCH METHOD

2.1. Participants

The respondents involved are school teachers in Malaysia. The total number of participants is 100 teachers from Kelantan, Malaysia. The sample was chosen based on random sampling method. A total of 26-item questionnaires examining mathematical knowledge were given to the participants. The participants were asked to assess mathematical knowledge. The five-point Likert scale format was used for the questionnaire. The data was collected in the standard curriculum distribution course for secondary schools, standard documents for curriculums, and mathematical testing of the fourth and fifth levels 2020–2021 by the Department of State Education of Kelantan, Malaysia.

2.2. Procedure

The Malaysian version of the mathematical knowledge scale consists of 26 items adopted from the Ernest mathematic knowledge framework [17]. A 5-point Likert scale (1=very much disagree, 2=disagree, 3=neutral, 4=agree, and 5=very much agree) was used. Respondents were asked to select the Likert scale that was very much related to their current situation. Before the scale was deployed to the participants, it was checked for face validity by two experts from Universiti Pendidikan Sultan Idris (UPSI) and Universiti Putra Malaysia (UPM). Other than that, the items were translated using back-to-back translation by an expert who had a Ph.D. in Malay language at UPSI. This is to confirm that the scale measures what it should be measured. After conducting face validity, the researcher asked two mathematicians in UPSI and Universiti Kebangsaan Malaysia (UKM), two expert mathematics teachers (GC), and a school improvement specialist coaches (SISC)+mathematics officer to examine the content validity of the scale. A list of experts is shown in Table 1.

Table 1. List of experts

Panel	Position	Experience	Validity
Panel A	Lecturer in UPSI (Mathematic Education)	>20 years	Content validity
Panel B	Lecturer in UPSI (Mathematic Education)	>20 years	Content validity
Panel C	Expert Teacher of Mathematics (Mathematic Education)	>30 years	Content validity
Panel D	Expert Teacher of Mathematics (Mathematic Education)	>30 years	Content validity
Panel E	Officer SISC+Mathematic School Improvement Specialist Coaches (Mathematic Education)	>30 years	Content validity
Panel F	Lecturer in UPM (Department of Basic Education)	>20 years	Face validity
Panel G	Lecturer in UPSI (Educational technology)	>20 years	Face validity
Panel H	Bahasa Melayu Teacher (Ph.D.) Faculty of Languages and Communications, UPSI	>10 years	Face validity

After conducting face validity and content validity, the researcher separated the scale from the participants. The data collection process was obtained permission from several agencies, such as the Department of Educational Policy Planning and Research and the Department of State Education of Kelantan. This is to confirm the ethical considerations of the data collection method. Before the data collection was performed, the researcher explained: i) the questionnaires did not intend to test the respondent's intelligence; ii) the purpose of the data collection was solely to contribute academically and as a contribution to knowledge; iii) the respondents hoped to answer the questionnaire honestly and sincerely; and iv) all the information obtained from this research is confidential and will not be distributed to any party.

2.3. Analysis

The scale's construct validity was investigated using factorial analysis [41]. According to Auerswald and Moshagen [42], EFA can assist researchers in developing theory by explaining the dimensionality of the instrument and determining whether the item empirically conforms to the specific construct. In this study, researchers used EFA to evolve existing components and locate objects for each factor. The distinguish variable in EFA was defined as the weighted sum of potentially associated factor variables and unique factors [43], [44]. Eigenvalue was greater than one, which was employed to keep the number of factors constant in this study. Theoretically, an eigenvalue greater than one indicates that the component explains more variance in the observed data than any single variable in the dataset [45], [46]. EFA was carried out using Statistical Package for the Social Sciences (SPSS) 22.0. The researchers initially used the basic principal components analysis, which was extracted with an eigenvalue greater than 1.

Furthermore, varimax rotation was used to make the data easier to read. Small coefficients up to 0.60 are likewise suppressed to present only items with factor loadings greater than 0.60 because the current research sample size was 100. According to Roover and Vermunt [47], factor analysis with 100 sample requires more than 0.6 factor loading. The current study took factor loading into account. It is because factor loading was linked to the connection of the items to the specific factor [46], [48]. Ehido *et al.* [49] define factor loading criteria as poor (0.32), fair (0.45), good (0.55), very good (0.63), and excellent (0.71). In the current study, factor loading was used to assign the item to a certain factor.

3. RESULTS

The appropriateness of the dataset to be used in factorial analysis was confirmed through Kaiser-Meyer-Olkin (KMO) and Barlett's test of sphericity. In the current research, the result of KMO was 0.842, and Barlett's test of sphericity was significant, which means the dataset can be used in factorial analysis. The result can be seen in Table 2.

A factorial analysis was conducted for 26 items using the SPSS 22 application. Principal components analysis with varimax rotation, and the coefficient was settled to 60 was performed. The data analysis with 100 participants revealed six factors with eigenvalues greater than 1, explaining 67.39% of the variance. Furthermore, the first factor explaining 41.85% of the variance indicates that the dataset is not common method biased. Specifically, the eigenvalue for the first factor was 15.064, the second factor was 2.659, the third factor was 1.970, the fourth factor was 1.722, the fifth factor was 1.481, and the sixth factor was 1.365. The detailed information about the eigenvalue and its variances can be seen in Table 3.

Table 2. The result of KMO and Barlett's test

KMO	Measure of sampling adequacy	0.842
Bartlett's test of sphericity	Approx. Chi-square sphericity	3025.96
	df	630
	Sig.	0.000

Table 3. Total variance

Component	Initial eigenvalues			Extraction sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of Variance	Cumulative %
1	15.064	41.845	41.845	15.064	41.845	41.845
2	2.659	7.385	49.230	2.659	7.385	49.230
3	1.970	5.472	54.701	1.970	5.472	54.701
4	1.722	4.784	59.485	1.722	4.784	59.485
5	1.481	4.113	63.599	1.481	4.113	63.599
6	1.365	3.793	67.391	1.365	3.793	67.391
.						
36	0.032	0.090	100.000			

Extraction method: principal component analysis

After determining the number of factors, the researcher examines the factor loading of each item's, which indicates which factor the items are correlated to, and whether the items will be eliminated or not from the analysis. In the current research, as the participants were 100, the items with a factor loading below 0.60 were eliminated from the analysis. The result found that there were three items in the first factor with factor loading ranged from 0.60 to 0.62, there were two items in the second factor with factor loading ranged from 0.72 to 0.75, there were five items in the third factor with factor loading ranged from 0.65 to 0.74, there were four items in the fourth factor with factor loading ranged from 0.70 to 0.75, there were ten items in the fifth factor with factor loading ranged from 0.60 to 0.79, and there were two items in the sixth factor with factor loading ranged from 0.64 to 0.68. Table 4 displays the result of factor loading for each item.

Table 4. Factor and factor loading

No	Items	Result of factor loading					
		1	2	3	4	5	6
Factor 1: mathematic content							
1	Covers a variety of procedures	0.602					
2	Covers a variety of strategies	0.622					
3	Strengthen the explanation and demonstration of teaching.	0.601					
Factor 2: related subject							
4	Applying mathematics in related fields		0.721				
5	Shows the relevance of the mathematical content to the student		0.759				
Factor 3: mathematic teaching							
6	Source of the subject's curriculum			0.698			
7	Computer software and teaching equipment			0.657			
8	Mathematical title-related approach			0.686			
9	Defining methods of solution, conceptualizing mathematical concepts, understanding difficulties and common student error			0.744			
10	Preparing tasks, activities and descriptions			0.613			
Factor 4: teaching management							
11	Command to group co-operative				0.750		
12	Asking questions to students in class				0.740		
13	Control aspects likening order in class				0.708		
14	Accessibility to teaching resources and conducting examinations				0.703		
Factor 5: contextual teaching							
15	Interactive methods like collaborate in a group					0.752	
16	Student response to learning tasks					0.684	
17	Student's response to teacher's authority					0.696	
18	Colleague and colleague in committee					0.607	
19	Classroom and location of teaching resources such as computer and audio					0.660	
20	Administrative rules and procedures of the teacher performance assessment system					0.670	
21	Out-of-class activities					0.793	
22	School culture					0.647	
23	The administrator's expectations of a teacher' duties					0.734	
24	Diversity of social, cultural and ethnic backgrounds of students					0.621	
Factor 6: knowledge of mathematics education							
25	Multiple mathematical theories						0.688
26	Results of empirical research						0.643

The research confirms six factors with their respective items. Each factor is then named based on the Ernest framework [17]. The first factor is named mathematic content, the second is named related subjects, the third is named mathematic teaching, the fourth is named teaching management, the fifth is named contextual teaching, and the sixth is named knowledge of mathematics education. Furthermore, researchers examine the scale's validity by revealing the Cronbach alpha value. The result showed that the current dataset has a Cronbach alpha of 0.958, which is categorized as a very high value, indicating the scale is valid to be used for research examining mathematical knowledge.

4. DISCUSSION

The purpose of this research is to develop the Malaysian version of the mathematical knowledge scale to be used by higher education teachers based on the Ernest framework [17]. Therefore, EFA was conducted. In the validation process, many researchers affirm that EFA procedures should be performed for each construction to determine whether the dimensions of the items have changed from previous studies [50]–[52]. The dimension of the item may change when the existing study differs from the previous study in terms of field of study, cultural differences, socio-economic population, and the time interval that is the period of the current study compared to the previous study. This means that the dimensions obtained by previous studies may not last, especially when the current studies are conducted in a new environment [34], [53].

In the EFA analysis of the current research involving a sample size of 100 teachers, the determined factor loading is more than 0.6, as recommended by Roover and Vermunt [47]. Research by Hair *et al*. [46] recommended a load factor of 0.55 and above, which is practically significant for a 100-person study sample. Supported by Baistaman *et al*. [54] which affirms that items are reliable when four or more factor loads have values greater than 0.6, regardless of sample size. The suitability of the sample data for analysis must be determined first by conducting the KMO and Barlett's test of sphericity tests. For this study, the EFA is consistent with the KMO value of 0.60 as a minimum value for a good factor analysis that indicates that the data does not have a serious multicollinearity problem [34], [35], [55]. In line with the suggestion by Bandalos [39] that stating KMO values approaching 1.0 can produce reliable and different factors among each other. Bartlett's test of sphericity uses a significance value (sig<0.05) to show sufficient correlation among variables to allow for the next test to be performed. Whereas the approved Eigen value is ≥1.0 for determining the number of factors representing the dimensions of a construct measured and considered significant within that number [36], [47].

This study confirms six factors of the scale, with the total items being 26. The number of factors in this research is concordance to the concept proposed by Ernest [17] in his research regarding the aspect of mathematics teachers that should be considered. The six factors are knowledge of mathematic content, knowledge of the subject matter, mathematic teaching (pedagogical and curriculum knowledge), knowledge of classroom organization and management, contextual teaching, and knowledge of mathematics education. The first factor in the scale is the mathematical content knowledge. In this research, this factor was found to have three items; the mathematical content includes procedures, the mathematical content includes strategies, and strengthening the explanation and demonstration of the content. Mainali [56] explained it as the pedagogical content knowledge which covers the ability of teachers to represent the subject, which is required for students to understand the materials. This includes analogy, illustration, and representing the mathematical concept in the best way it is possible [56]. Roubicek [57] stated that no material can be obtained by students without a presentation. It exactly helps students grasp the abstract notion of the mathematical content [58]. Therefore, strengthening explanation and demonstration in mathematical teaching is one of the essential strategies and procedures that should be implemented by teachers.

The second factor in the scale is the knowledge of the subject matter, which includes two items which are applying mathematics in a related field and showing the relevance of the mathematical content to the students. Based on the explanation in the introduction to this research, mathematics content can be used in other related fields because it trains students to do problem solving, reasoning, connecting, and representing [2]. Study by Maamin *et al*. [14] stated that students need mathematical understanding to produce a workplace and contribute to the country. Mathematic has been integrated into one of the subjects prepared for the industrial work market, namely science, technology, engineering, and mathematics (STEM). Tamur *et al*. [59] explained that there is a demand for competencies to fulfil the economic industry, and mathematics is named as one of the areas of literacy that must be invested in to increase the competencies. Wolff *et al* [60] stated that students who complete mathematics classes have greater chance of getting a degree. A bachelor in mathematic is two-thirds of the fastest-growing job requirement. Therefore, a mathematics teacher should equip students with mathematical understanding and mastery. To do that, it is related to the third factor of the scale, namely mathematics teaching. Mathematics teaching includes the items of the subject curriculum, integrated technology in teaching, conceptualizing the mathematic materials for the students, and preparing tasks for the students to solve. This strategy aims to enhance the quality of teaching, which can boost student achievement and mastery in mathematics.

The fourth factor on the scale is teaching management. In this research, this factor includes five items which are managing a cooperative group of students, provoking by asking and answering questions in the classroom, ordering the classes, access to teaching resources, and preparing examinations. Mainly, teaching students is ordering them into classroom activities. Eraut [61] stated that managing the classroom involves utilizing a series of events that occur in the classroom by the teacher in countless ways. Several ways of managing the classroom that can give teachers effective performance are to take actions as the response to the event occurs, pursue specific action, and keep metacognitive monitoring [62]. In this case, monitoring student metacognitive performance is related to assessment actions conducted by teachers. Teacher classroom management is essential for teacher wellbeing and students' academic success [63]. Yuwandra and Arnawa [64] stated that teacher classroom management can enhance the effective time used in the classroom, establish effective learning outcomes, and improve behavioral management. Therefore, examining classroom management is essential for any subject teacher, including math. That is why Ernest in his model [17], includes this domain as one of the aspects that must be considered for effective mathematical teaching. Researchers, through the scale validated in this research, can examine the effectiveness of teacher management in the classroom.

The fifth factor for the scale was contextual teaching. Contextual teaching includes items such as interactive group teaching strategies, student responses, peer support, the availability of devices to support learning, administrative procedures and procedures of assessment, school culture, outside-class activities, the expectation of the administration of teacher duties, and the background of the students. These variables support the contextual teaching performed by teachers. According to Uslima *et al*. [65], contextual teaching supported by various equipment could improve students problem-solving abilities, understanding of concepts, and learning outcomes. Orland-Barak and Wang in their research [66], found that the use of contextual learning can improve students mathematical understanding. Wolff *et al*. [60] also conclude in their research that the use of contextual learning by teachers is 76% higher than the use of traditional methods. Therefore, emphasizing the teacher's mathematic and contextual learning is important. Through this scale, researchers can contextualize the teacher's mathematic contextual learning, which is supported by facilities, through the items found in this research. It indicates the need to utilize this scale in actual research.

The sixth factor of the scale is the general understanding of the teacher regarding mathematic education, such as theories of mathematics and research related to mathematic education. This is to make sure that teachers have a rich, wide, and comprehensive understanding regarding mathematical education and teaching. Teacher professional development should develop a more comprehensive and deeper understanding of educational issues. This can be acquired by teachers who learn about mathematic teaching and learning theories as well as the current research related to mathematic teaching and learning. Both theories related to mathematics education and the current research trend in mathematics are considered to examined on the current scale. Therefore, the comprehensive aspect of the teacher is covered by the scale. Overall, this research contributes to confirming a valid scale to be used for examining teacher math knowledge. The scale can be used in research to examine the proficiency and mastery of the teacher in teaching mathematics. According to Mainali [56], students should understand the subject, but teachers are the ones who have the responsibilities in the implementation of the curriculum in the classroom.

5. CONCLUSION

The purpose of the current research was to determine the validity of the Malaysian version of mathematical knowledge of teachers. The scale was tested with exploratory factor analysis and Cronbach alpha. In exploratory factor analysis, eigenvalues are greater than one and factor loading are considered. Based on the consideration, there are six factors with 26 items framed. The structure of the scale can be broken down as: three items in the first factor, two items in the second factor, five items in the third factor, four items in the fourth factor, ten items in the fifth factor, and two items in the sixth factor. The factorial analysis confirmed the structure of the scale. Furthermore, the reliability of the scale was confirmed through Cronbach's alpha. The result of Cronbach alpha confirms that the scale was reliable to be used in the study, with a value of 0.958. Based on the results, the scale are valid and reliable enough to be used to measure teachers' mathematical knowledge.

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