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Validity and Reliability of Pre-Service Teacher Competency Level in Teaching Early Mathematics Instrument Using the Rasch Model

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ABSTRACT

The Pre-Service Competency Teacher Level in Teaching Early Mathematics Instrument has been developed to measure the competency level and readiness to teach early mathematics in Preschool. This study was conducted to produce empirical evidence on the validity and reliability of this instrument by using the Rasch model. Surveys were conducted in three private universities that offer Early Childhood Education Programmes. A total of 85 pre-service teachers were selected as a sample of the study through simple random sampling. The validity and reliability of the instrument were measured using Rasch's model through Winstep software version 3.68.2. The findings of the unidimensionality test showed 46.1%. The Rasch analysis shows the person reliability index is 0.8 with a separation index is 2.05. The item reliability index is 0.91 and the separation index is 3.18. The item fitness analysis found 29 items in the instruments are in the valid range and one item that falls out of the allowed range. The finding showed that this instrument has a high degree of validity and reliability and can be used to measure the competency level of pre-service teaching in teaching early mathematics.

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1. INTRODUCTION

Early Mathematics is one of the important subjects that need to be taught to young children. Early exposure to mathematics fosters cognitive development in young children (Ghazali et al., 2021). It encourages them to think logically, analyze situations, and solve problems. These foundational skills form the basis for more advanced mathematical concepts in later stages of education. It is important to cultivate these thoughts starting from a very young age (Jiang & Xiong, 2021). Children's learning in the early years confirms the importance of early experiences in mathematics for later educational success (Mariano et al., 2019). The quality of early childhood education influences children's competencies leading to successful adulthood, and math skills are one of the most influential factors. The study shows that most children acquire basic mathematical knowledge and skills before the age of eight. That is why early mathematics is one of the compulsory subjects in early childhood education curriculum.

Young children are adept at learning mathematics. Research has repeatedly shown how a variety of children's daily routines, games, and interests can be utilized to engage, stretch, and educate young talents and expertise in mathematics. There is now substantial evidence that the best learning environments for young children blend the benefits of teacher-initiated group work with those of children independently selected, but potentially educational, play activities (Nguyen et al., 2016). To effectively capture the learning opportunities in the child's surroundings and provide a variety of relevant tools and purposeful and challenging activities, teachers in early childhood settings need a solid understanding of mathematics. Effective teachers use this understanding to give scaffolding that expands the child's mathematical thinking while also appreciating the child's input (Fuson et al., 2015).

Some preschool and kindergarten have become overly academically focused at the expense of play, discovery, and non-academic topics like social development (Bjorklund et al., 2020). Furthermore, Bassok et al. (2016) found that teacher-directed activities, including the use of textbooks and worksheets, have increased dramatically. Teachers' beliefs about mathematics influence their teaching, and teachers with different beliefs about mathematics teach differently (Lester & Chai, 2016). Teachers are central to promoting the affective atmosphere and social interaction in the classroom and their beliefs have a significant impact on the nature of teaching practice (Pehkonen et al., 2016). Therefore, to ensure early mathematics can be taught more creatively and effectively, teachers must be trained enough to make sure that they are competent enough to teach early mathematics.

Preservice teachers are prospective teachers who will teach early childhood education after graduation. They undergo their training in the university or training college and is not yet a certified practicing teacher. In this study, the preservice teachers are the students of Bachelor of Early Childhood Education in three different universities in Malaysia. It is important to study on preservice teacher belief, knowledge, skill, attitudes, and competencies level in teaching and learning to ensure the effectiveness of their training. There are several studies in early childhood education involving preservice teachers (Kim & Connelly, 2019; Zhulamanova & Raisor, 2020; Boone, 2016; Aldemir & Sezer, 2009; Kulaksız & Toran, 2022; Jiang & Xiong, 2021).

2. METHODS

The purpose of this instrument is to explore preservice preschool teachers' competency level of preschool mathematics in teaching early mathematics. This instrument was

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developed in a workshop with researchers, and teachers. This instrument was piloted to find out whether the teachers understand the questions and was able to answer the question as expected.

The instrument was developed based on three constructs, specifically preservice teacher's knowledge about preschool mathematics, preservice teacher's understanding about importance of preschool mathematics and the third construct is preservice teachers' attitudes towards preschool mathematics.

The first construct on preservice teachers' knowledge about preschool mathematics practices and curriculum consists of 10 items measured on a 3-point Likert scale ranging from 'Incapable' coded as '1' at one end to 'Very capable' coded as '3'at the other end. On preservice teachers' knowledge about preschool mathematics, this research focuses on 10 items which are numbers writing, comparing objects based on particular characteristics, numbers comparing, classifications of objects, object arranging, identical and non-identical pair object matching, object matching, number concepts, games and simple mathematical operation problem solving.

The second construct on preservice teachers' understanding about the importance of mathematics consists of 10 items measured on a 3-point Likert scale ranging from 'Not important' coded as '1' at one end to 'Very important' coded as '3'at the other end. The third construct on preservice teachers' attitudes towards consists of 7 items measured on a 3-point Likert scale ranging from 'Disagree' coded as '1' at one end to 'Strongly agree' coded as '4'at the other end.

2.1. Population and Sampling

To obtain 95% of confidence level in Rasch Measurement Model, the minimum size sample required is between 64 to 144 (Toffoli, 2016). Meanwhile, the total of 85 preservice teachers from three different universities in Malaysia were involved in this study using the simple random sampling technique.

2.2 Data Analysis

The data gathered from the survey analyzed using the computer software namely WINSTEP to obtain the value of validity and reliability of the instrument. The instrument consists of 27 items in four parts which are Part A: Demography; Part B: Knowledge about preschool mathematics (10 items); Part C: Understanding about importance of numeracy (10 items); and Part D: Attitudes towards numeracy (7 items). Details of the instrument are shown in the **Table 1** below.

Several analyses were done using Rasch Model to check person and item reliability and separation index; unidimensionality; item polarity; and item fit and misfit. The diagnosis of the four aspects have completed the requirements of the validity check and required instrument reliability in Rasch Measurement Model (Yunus et al., 2017).

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Table 1. Items in the Instrument.

CONSTRUCT	SUB-CONSTRUCT	
Knowledge about Preschool Mathematics. Give your respond based on scale: 1: Incapable 2: Not Sure 3: Capable.	A1	I am able to teach my preschool children writing numbers
	A2	I am able to teach my preschool children comparing objects and numbers.
	A3	I am able to teach my preschool children about classification of objects.
	A4	I am able to teach my preschool children about seriation.
	A5	I am able to teach my preschool children about matching one-to-one.
	A6	I am able to teach my preschool children about matching objects in the environment.
	A7	I am able to teach my preschool children about simple measurement.
	A8	I am able to teach my preschool children about number concepts.
	A9	I am able to teach my preschool children about exercises/activities with learning materials/games
	A10	I am able to teach my preschool children about simple problem solving.
Understanding about importance of preschool mathematics Give your respond based on scale: 1: Not Important 2: Not Sure 3: Important Are the following activities important in enhancing preschool children's knowledge about numeracy?	B1	Counting numbers
	B2	Writing numbers
	B3	Comparing objects and number
	B4	Classifying objects
	B5	Matching objects in the environment
	B6	Mathematical games
	B7	Doing exercises with other children
	B8	Doing homework/exercises
	B9	Doing exercises with materials/games
	B10	Simple problem solving
Attitudes towards numeracy Give your respond based on scale: 1: Strongly disagree 2: Disagree 3: Agree 4: Strongly agree I think that ...	C1	Only parents are responsible to teach preschool children about numeracy.
	C2	Activities in the preschool could be related to numeracy.
	C3	All children have the opportunity to excel/succeed in mathematics.
	C4	I can assist my preschool children to enhance mathematical knowledge.
	C5	My involvement in learning will enhance my preschool children's positive attitudes towards mathematics.
	C6	It is important for children to have fun while learning mathematics.
	C7	I have a role in inculcating positive attitudes towards mathematics among children.

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3. RESULTS AND DISCUSSION

3.1. Unidimensionality

One of the most important considerations in the construction of an instrument or measurement tool is to ensure that the instrument is unidimensional. Unidimensionality assumes that the items in the instrument or questionnaire measure a single ability (Van Zile-Tamsen, 2017).

In the Rasch model, unidimensionality refers to the assumption that the items in an instrument or questionnaire measure a single underlying construct or trait. This means that all items are related to each other through the common properties being measured and do not reflect multiple dimensions or factors. In assessing unidimensionality, Rasch Model stated a few criteria need to be fulfilled which are: a) raw variance explained by the measurement of at least 40% (Adi et al., 2022); and b) the unexplained variance in the first contrast is no more than 15% (Rushdi & Asbulah, 2022).

The result of this study showed that the Raw Variance explained by the Measurement is 46.1% and 6.5% respectively for the unexplained variance in the first contrast. This result indicates that the instrument is unidimensional and meets the requirements of Rasch Model Analysis of Unidimensionality. The result of analysis is stated in the **Figure 1** below.

Table of STANDARDIZED RESIDUAL variance (in Eigenvalue units)

		-- Empirical --			Modeled
Total raw variance in observations	=	50.1	100.0%		100.0%
Raw variance explained by measures	=	23.1	46.1%		45.9%
Raw variance explained by persons	=	9.6	19.1%		19.0%
Raw Variance explained by items	=	13.6	27.1%		26.9%
Raw unexplained variance (total)	=	27.0	53.9%	100.0%	54.1%
Unexplned variance in 1st contrast	=	3.3	6.5%	12.1%	
Unexplned variance in 2nd contrast	=	2.4	4.7%	8.8%	
Unexplned variance in 3rd contrast	=	2.1	4.2%	7.7%	
Unexplned variance in 4th contrast	=	2.0	3.9%	7.3%	
Unexplned variance in 5th contrast	=	1.8	3.7%	6.8%	

STANDARDIZED RESIDUAL VARIANCE SCREE PLOT

Figure 1. Data analysis for Unidimensionality.

3.2 Reliability

In the context of the Rasch model, reliability refers to the consistency or accuracy of the candidate (person) being assessed or evaluated and the item parameters. The Rasch model assumes that a person's probability of endorsing an item is a function of the difference between a person's ability and the item's difficulty.

There are few requirements that need to be considered in the reliability of using the Rasch Model, which are person and item reliability and the separation index. The individual reliability value means the assumption that the abilities of individuals in the sample are consistent despite being given a different set of items but still measuring the same construct (Toffoli, 2016). Meanwhile the reliability value of the item means that the item is sufficient to measure what it wants to measure. Separation index is an index that classifies individuals or items into several groups. Individual and item separation index values greater than 2 are considered good (Soeharto & Rosmaiyadi, 2018).

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The result of the study showed that the value of person reliability is 0.81 separation index is 2.05. For the item reliability the value is 0.91 meanwhile separation index is 3.18. This result show that the instrument has a high reliability value and good separation index (Boone & Noltemeyer, 2017). The result is presented in the **Table 2** below:

Table 2. Person and Item Reliability and Separation Index.

PERSONS	85 INPUT		85 MEASURED		INFIT		OUTFIT	
	SCORE	COUNT	MEASURE	ERROR	IMNSQ	ZSTD	OMNSQ	ZSTD
MEAN	76.2	27.0	2.08	.49	1.03	.0	.86	-.1
S.D.	7.1	.0	1.18	.15	.52	1.3	.55	1.3
REAL RMSE	.52	ADJ.SD	1.06	SEPARATION	2.05	PERSON RELIABILITY		.81
ITEMS	27 INPUT		27 MEASURED		INFIT		OUTFIT	
MEAN	238.9	85.0	.00	.26	.98	.0	.86	-.2
S.D.	27.4	.0	.86	.04	.31	1.4	.46	1.8
REAL RMSE	.26	ADJ.SD	.82	SEPARATION	3.18	ITEM RELIABILITY		.91

3.3 Item Polarity

Analyzing item polarity aims to detect the extent to which the construction of the construct achieves its goal through positive and negative values. Item polarity is analyzed through the Point Measure Correlation (PTMEA CORR) value in WINSTEP. According to Boone & Noltemeyer (2017) if any value found in the PTMEA CORR section is a positive value, it indicates that the item measures the construct that is to be measured, on the other hand if the value shown is negative, the items developed is not able to measure the construct that is intended to be measured. The item with the negative value needs to be checked or dropped from the instrument. **Table 3** showed the PTMEA CORR for all items in the instrument. Based on the result, all items showed positive value, and this indicates that all items are able to measure the competencies of teaching early mathematics among preservice teachers.

Table 3. PTMEA CORR Values of Item Polarity.

ENTRY NUMBER	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PT-MEASURE CORR.	PT-MEASURE EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	ITEM	G
21	163	85	3.25	.18	2.34	6.1	2.79	7.7	.11	.61	45.1	57.7	C1	0
19	242	85	-.23	.35	.88	-.5	.59	-.9	.42	.32	87.8	86.9	B9	0
7	221	85	.16	.22	1.28	1.6	1.24	1.0	.45	.54	64.6	69.7	A7	0
18	207	85	.96	.19	1.26	1.6	1.50	1.9	.46	.56	54.9	61.7	B8	0
4	209	85	.10	.23	1.13	.9	1.12	.8	.49	.56	67.1	69.2	A4	0
13	243	85	-1.02	.33	1.04	.2	.67	-.4	.51	.49	86.6	88.4	B3B	0
17	233	85	-.24	.25	.98	.0	1.08	.3	.52	.52	81.7	79.4	B7	0
10	219	85	.31	.22	1.05	.3	1.00	.1	.53	.55	62.2	67.4	A10	0
24	266	85	1.51	.23	.98	-.1	.96	-.2	.54	.54	76.8	69.6	C4	0
12	238	85	-.35	.27	.91	-.2	.51	-.9	.55	.50	82.9	84.4	B2	0
9	233	85	-.44	.26	.90	-.4	.68	-.9	.57	.52	80.5	79.1	A9	0
1	231	85	-.05	.24	.87	-.5	.68	-.8	.57	.52	76.8	78.0	A1	0
15	235	85	-.84	.28	.90	-.4	.66	-1.0	.57	.52	80.5	80.7	B5	0
16	243	85	-1.02	.33	.78	-.6	.46	-1.0	.58	.49	90.2	88.4	B6	0
6	230	85	-.03	.24	.90	-.4	.61	-1.1	.58	.52	76.8	77.0	A6	0
23	273	85	.31	.20	1.14	.9	1.12	.8	.58	.63	63.4	63.3	C3	0
14	235	85	-.49	.27	.87	-.5	.56	-1.2	.58	.51	80.5	81.1	B4	0
11	245	85	-1.07	.36	.73	-.7	.27	-1.3	.59	.49	91.5	90.6	B1	0
2	234	85	-.81	.27	.85	-.7	.64	-1.1	.60	.52	84.1	79.8	A2	0
3	221	85	.27	.22	.84	-.9	.81	-.7	.60	.54	70.7	69.5	A3	0
20	233	85	-.44	.26	.81	-.9	.57	-1.3	.61	.52	84.1	79.1	B10	0
25	268	85	.45	.22	1.01	.1	.93	-.3	.62	.62	74.4	68.7	C5	0
8	229	85	-.15	.24	.75	-1.3	.58	-1.5	.62	.53	75.6	76.0	A8	0
5	232	85	-.22	.25	.63	-1.9	.92	-.1	.63	.52	84.1	78.7	A5	0
26	311	85	-.36	.22	.76	-1.0	.60	-1.4	.66	.58	81.7	74.9	C6	0
27	284	85	.11	.20	.90	-.6	.85	-.9	.67	.62	69.5	65.0	C7	0
22	271	85	.36	.20	.89	-.6	.90	-.6	.68	.62	75.6	65.0	C2	0
MEAN	238.9	85.0	.00	.25	.98	.0	.86	-.2			75.9	75.2		
S.D.	27.4	.0	.86	.05	.31	1.4	.46	1.8			10.7	8.7		

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3.3 Item Fit and Misfit

Next procedure is to measure fit, and misfit of items in the instrument. Fitness of items in measuring the construct can be seen through the Mean-Square or MNSQ infit and MNSQ outfit values. The value of MNSQ outfit and MNSQ infit should be in the range between 0.5 to 1.5 logits to ensure that the items developed are suitable for measuring the construct (Boone & Noltemeyer, 2017). However, the MNSQ outfit index needs to be given attention first compared to infit to determine the appropriateness of items that measure a construct or latent variable (Rushdi & Asbulah, 2022). The item is considered deceptive if the MNSQ value exceeds 1.5 logits. The item is too readily anticipated by the individual if the MNSQ score is less than 0.5 logits (Adi et al., 2022). If the outfit and infit MNSQ values are in the range, the ZSTD index can be disregarded (Adi et al., 2022). But the outfit ZSTD and infit ZSTD values should also be in the range of -2 to +2 (Boone & Noltemeyer, 2017). If these requirements are not met, the item might need to be removed or rechecked.

Table 4 showed the MNSQ values for each item in this instrument. Based on the result, 26 items showed the values of MNSQ in the range of 0.5-1.5 which mean are fit in this instrument and one item showed the MNSQ Outfit and Infit out of the range which is item C1 (Outfit: 2.79; infit: 2.34). This item needs to be rechecked or consider to be dropped from the instrument.

Table 4. Item Fit and Misfit.

ENTRY NUMBER	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PT-MEASURE CORR.	PT-MEASURE EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	ITEM	G
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12	238	85	-.35	.27	.91	-.2	.51	-.9	.55	.50	82.9	84.4	B2	0
9	233	85	-.44	.26	.90	-.4	.68	-.9	.57	.52	80.5	79.1	A9	0
1	231	85	-.05	.24	.87	-.5	.68	-.8	.57	.52	76.8	78.0	A1	0
15	235	85	-.84	.28	.90	-.4	.66	-1.0	.57	.52	80.5	80.7	B5	0
16	243	85	-1.02	.33	.78	-.6	.46	-1.0	.58	.49	90.2	88.4	B6	0
6	230	85	-.03	.24	.90	-.4	.61	-1.1	.58	.52	76.8	77.0	A6	0
23	273	85	.31	.20	1.14	.9	1.12	.8	.58	.63	63.4	63.3	C3	0
14	235	85	-.49	.27	.87	-.5	.56	-1.2	.58	.51	80.5	81.1	B4	0
11	245	85	-1.07	.36	.73	-.7	.27	-1.3	.59	.49	91.5	90.6	B1	0
2	234	85	-.81	.27	.85	-.7	.64	-1.1	.60	.52	84.1	79.8	A2	0
3	221	85	.27	.22	.84	-.9	.81	-.7	.60	.54	70.7	69.5	A3	0
20	233	85	-.44	.26	.81	-.9	.57	-1.3	.61	.52	84.1	79.1	B10	0
25	268	85	.45	.22	1.01	.1	.93	-.3	.62	.62	74.4	68.7	C5	0
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27	284	85	.11	.20	.90	-.6	.85	-.9	.67	.62	69.5	65.0	C7	0
22	271	85	.36	.20	.89	-.6	.90	-.6	.68	.62	75.6	65.0	C2	0
MEAN	238.9	85.0	.00	.25	.98	.0	.86	-.2			75.9	75.2		
S.D.	27.4	.0	.86	.05	.31	1.4	.46	1.8			10.7	8.7		

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4. CONCLUSION

In conclusion, the assessment of validity and reliability of the pre-service teacher competency level in teaching early mathematics instrument using the Rasch Model has provided valuable insights into the effectiveness of this assessment tool. Validity refers to the extent to which an instrument measures what it is intended to measure, and reliability pertains to the consistency and stability of the instrument's results over time. The utilization of the Rasch Model in this study has demonstrated promising outcomes in terms of both validity and reliability.

The validity of the instrument was substantiated through rigorous item analysis, item polarity, person, and item reliability as well as separation index. This ensures that the instrument accurately assesses the preservice competencies related to teaching early mathematics. Overall, the findings of this study suggest that the instrument for assessing pre-service teacher competency in teaching early mathematics, using the Rasch Model, holds promise in terms of both validity and reliability. However, it is essential to continue monitoring and refining the instrument to ensure its continued effectiveness and accuracy in assessing teacher competency in this critical area of education. This research contributes to the ongoing efforts to improve teacher preparation programs and enhance the quality teaching early mathematics in early childhood education and improving the professionalism among preservice teachers.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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