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Validity of instrument to measure mathematics teachers' perceptions towards problem-based learning activities

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ABSTRACT

Problem-based learning (PBL) is a proposed method for teaching mathematics in primary education in the education 4.0 era. This method enables teachers to conduct effective instruction by allowing students to explore alternative solutions to problems. This study was conducted to develop and validate an instrument for evaluating primary school mathematics teachers' perceptions of PBL activities. This research is quantitative, and a questionnaire was employed to collect data. The data obtained were analyzed descriptively utilizing Cronbach's alpha and exploratory factor analysis (EFA). It is determined that Cronbach's alpha is 0.885, with a factor eigenvalue greater than 1. The Kaiser–Meyer–Olkin (KMO) value for each construct is 0.50, whereas Bartlett's test value is statistically significant (<0.5). Each item has a factor loading of 0.50 or higher and a standard deviation of ≥60%. This study's results indicated that this instrument can be used to investigate primary school mathematics teachers' perceptions of PBL activities involving group division, generating ideas and learning issues, identifying problems, self-directed learning, synthesis and application, reflection, and assessment.

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1. INTRODUCTION

The introduction of the industrial revolution 4.0 (IR 4.0) has affected our development and human civilization in general. It significantly impacts how humans live and work, including increased efficiency and productivity, greater customization of products, and the creation of new job opportunities [1]. IR 4.0 brings more distinct changes from the previous three as technological advancements have made it possible to merge biological, physical, and digital worlds to form different disciplines [2]. In today's modern world, teachers are encouraged to improve the quality of teaching to fulfill the requirements and demands of IR 4.0. Various new terms have been introduced to ensure that education is implemented following the 4.0 era, such as education 4.0 [3].

Education 4.0 encourages students to apply the concepts, principles, and procedures they learn in school [4]. Communication, collaboration, critical thinking, creativity, and problem-solving are essential for employment in the IR 4.0 era. These skills are considered essential for employment in the IR 4.0 era as they are necessary for workers to effectively navigate and utilize the advanced technologies being integrated into the workforce [5]. The workers need to be adaptable and continuously learn new skills to keep up with the rapid pace of technological advancement. Hence, teachers are advised to cultivate these skills by implementing project-based learning and problem-solving in their classrooms to prepare students for real-world challenges [6].

Problem-based learning (PBL) is a teaching method that is considered well-suited to the education system of the 4.0 era. This method emphasizes acquiring knowledge and skills through the active engagement of students in solving real-world problems [7]. This method aims to help students develop the critical thinking, problem-solving, and collaboration skills that are essential for success in the IR 4.0 era. Besides, it allows students to independently reflect on and implement their learning [8]. It uses various learning resources to assist students in resolving given issues or problems. Students can also explore learning by identifying various alternative solutions to given problems.

Additionally, PBL helps teachers form learning based on social constructivism by involving students actively in the learning process [9]. It allows students to learn independently, build knowledge, and exchange views with friends. Implementing this method can also increase students' commitment to their learning process [10]. This method differs from conventional learning, where learning occurs multi-directionally between students and teachers. Students work in small groups to identify and solve a complex problem or scenario. This process requires them to actively seek out information, analyze data, and develop solutions, which helps them develop critical thinking and problem-solving skills [11].

Furthermore, PBL allows students to explore possible solutions to the given problems. Teachers expose students to structured steps and procedures to assist them in solving problems effectively [12]. The steps include ideation, investigation, testing, implementation, synthesis, and formulation. As a result, the activity encourages critical thinking, new knowledge and skills testing, and logical comparisons [13]. Thus, students can apply the knowledge and skills they have learned to solve complex and challenging problems. At the same time, students can see the relevance and application of the knowledge and skills they have learned, which can increase their motivation and engagement in the learning process.

In conclusion, PBL is suitable to be implemented in mathematics education. However, before implementing PBL in the classroom, especially in primary school, there is a need to identify suitable PBL tasks and activities. Thus, this study was driven by the need to develop an appropriate research instrument to identify suitable PBL activities in the context of primary education. Therefore, this study was conducted to develop and validate an instrument for measuring primary school mathematics teachers' perceptions of PBL activities.

2. LITERATURE REVIEW

There have been numerous studies on the impacts of PBL on students. Previous studies [14], [15] have generally found that PBL is an effective teaching method that can lead to positive student outcomes, such as improved critical thinking, problem-solving, and collaboration skills and increased motivation and engagement in the learning process. According to Balim *et al*. [16], this method can foster an active learning environment in the classroom. Students provided positive feedback as they engaged in learning activities using this method. The activities have helped students generate and explore new ideas to enhance their comprehension of the lesson's concepts and reduce misconceptions about the learning materials [17].

The study's findings are supported by Kuo *et al*. [18] who found that students' active participation in learning can help them acquire new knowledge and skills through an open problem-solving process. Students' collaboration with their peers allows them to examine problems critically and provides them with opportunities to communicate, exchange perspectives, and generate solutions to the problem [19]. Thus, it helps students develop a deeper understanding of the problem and the potential solutions. In addition, it improved students' ability to transfer knowledge to new and unfamiliar contexts, an essential skill for success in the IR 4.0 era.

Research by Ogunsola *et al*. [20] found that teachers' teaching practices are improved when they consider the distinctions between conventional and PBL methods. Teachers also attempt to pique students' interest in learning by facilitating group-based learning and encouraging students' participation through this activity. In this regard, the teacher's guidance and instructions during the learning process can aid students in engaging in meaningful learning. In PBL, the teacher acts as a facilitator, guiding students through the problem-solving process rather than providing them with all the answers [21]. This allows students to take a more active role in their learning and to develop their critical thinking and problem-solving skills.

Maidan *et al*. [22] showed that students who learn through PBL have higher science process skills than those receiving traditional instructions. Science process skills refer to students' ability to make problem statements and hypotheses and their ability to find solutions to these problems. Students who engage in PBL also have higher motivation, higher value of biological learning, and clearer behavioral targets due to the stimulation component in the learning environment [23]. It is because PBL is goal-directed and helps students to understand what they need to do to reach their goals. This allows students to focus on the specific skills they need to develop and provides them with a clear understanding of what they need to do to be successful.

Previous studies have concluded that this method positively affects students' cognitive abilities. PBL allows students to engage in a structured learning procedure designed to help them acquire knowledge and solve problems. However, the scope of these studies is limited to the impact of implementing the PBL without examining appropriate classroom learning activities. Besides, there are limited studies on PBL implementation in teaching primary-level mathematics [16]–[22]. In this light, the researchers believe this circumstance has created a gap that must be filled. Hence, this study was conducted to develop and validate an instrument to measure primary school mathematics teachers' perceptions of PBL activities.

3. RESEARCH METHOD

This study employed the survey method to assess a large population's perceptions, opinions, and beliefs [24]. Surveys can be used to collect data from a large number of samples in a relatively short amount of time. The number of samples selected in the survey method is crucial because it can affect the study results. Generally, the number of samples is determined by the population size and the desired precision and confidence in the results [25]. In this study, the number of samples is based on the loading factor value presented by [26]. They suggest a factor loading of 0.50 is adequate for a sample size of 120 individuals. This means that when using factor analysis with a sample size of 120 individuals, a factor loading of 0.50 is considered sufficient to provide reliable results. Thus, this study involved a sample of 120 primary school mathematics teachers.

The researchers developed the questionnaires based on the PBL model by Wee [27]. This model focuses on an active learning approach that emphasizes student-centered learning and using real-world problems as the basis for learning. Implementing this model can help students develop critical thinking, problem-solving, and self-directed learning skills and improve their motivation and engagement in learning. According to Wee [27], the PBL method involves seven processes; group division, identifying problems, generating ideas, learning issues, self-directed learning, synthesis and application, and reflection and assessment. These seven processes refer to the sub-construct to develop an appropriate research instrument to identify suitable PBL activities in primary education.

There are two components to this instrument: parts A and B. There were five statements in part A require samples to answer questions on their basic gender information, teaching experience, information and communication technologies (ICT) proficiency, types of mobile devices, and level of proficiency with those devices. Within part B, there were four seven-construct containing a total of 32 items measuring the construct of PBL activities in primary education, as shown in Table 1. The details of the items for each sub-construct are presented in Table 2.

In this study, the researchers evaluated the variables using a 5-point Likert scale. The 5-point Likert scale is a particular type of Likert scale that requires respondents to rate a statement's agreeability or disagreeability on a range of 1 to 5. The researchers in this study utilized a Likert scale with the following options: strongly disagree=1, disagree=2, neither agree nor disagree=3, agree=4, and 5=strongly agree [28]. The face and content validity of the instrument was evaluated before the pilot study to assess its quality. Face validity refers to the degree to which an instrument looks to measure what it is supposed to measure. In contrast, content validity describes how well the instrument represents all elements of the construct it is intended to assess [26]. It evaluates whether the instrument's questions or items accurately reflect the sub-construct of the construct being measured.

Thus, the face and content validity procedures involved four experts in Malay studies, curriculum, mathematics education, and assessment and evaluation. According to Polit *et al*. [29], the content validity index must be evaluated by a minimum of three experts. This group of experts must determine: i) if the proposed item is appropriate; ii) if the number of items is adequate; iii) if the correct language, sentence structure, and terminology are used; and iv) evaluate the items on a 5-point scale. Based on the expert review, 10 items were removed from the sub-constructs of group division, identifying problems, generating ideas, learning issues, self-directed learning, synthesis and application, and reflection and assessment. The number of items in the pilot study was reduced from 42 to 32, as described in Table 1.

Then, the researchers conducted the pilot study using the remaining items in the questionnaire. The software for IBM SPSS version 20 was used to analyze the data from the pilot study. By using the data, the researchers conducted an exploratory factor analysis (EFA) and Cronbach’s alpha test to determine the instruments' construct validity and reliability. EFA procedure must be carried out to ensure that every sub-construct item is suitable and adequate for measuring the specified constructs [26]. Three primary considerations were made, sample size, correlation matrix, and sampling adequacy. As shown in Table 3, numerous sampling adequacy tests have been conducted to determine the sample's adequacy and the data's suitability [30].

This research employed principal component analysis (PCA) with varimax rotation to evaluate the clarity of each item within each sub-construct [26]. In addition, parallel analysis techniques could be utilized to determine the number of factors that require elimination or maintenance [31]. Meanwhile, the eigenvalues were used to determine the number of factors required in the instrument.

Table 1. Details of questions item

Construct/sub-construct	Numbers of items
Group division	5
Identifying problem	5
Generate ideas	5
Learning issue	4
Self-directed learning	3
Synthesis and application	5
Reflection and assessment	5
Total	32

Table 2. Details of questions item based on construct

Construct	Item	
Group division	Create a group with members of different abilities.	GD1
	Determine the abilities of each member.	GD2
	Divide tasks based on the abilities of each team member.	GD3
	Accept responsibility for tasks assigned	GD4
	Work together as a group to complete assigned tasks.	GD5
Identifying problems	Understand the problem (question) given based on the stimulus material shown.	IP1
	Restate the given problem using your own words.	IP2
	Relating problems to past learning (existing knowledge)	IP3
	Relating problems to real-life situations.	IP4
	Get other friends' views on the given problem.	IP5
Generating ideas	Get various ideas from supporting materials such as the internet.	GI1
	Get various ideas from supporting materials such as the internet.	GI2
	Share ideas gained with members.	GI3
	Using various learning applications to get ideas.	GI4
	Identify what they need to learn and master.	GI5
Learning issues	Plan steps to solve the given problem.	LI1
	Choose the most appropriate solution to solve the problem.	LI2
	Rechecking the solution steps that have been selected.	LI3
	Understand each step in the selected troubleshooting procedure.	LI4
Self-directed learning	Discuss in detail each step in the group.	SL1
	Determine what needs to be done in each step.	SL2
	List keywords for each solution step.	SL3
Synthesis and application	Solve problems by doing group discussions.	SA1
	Solve the problem by using the selected solution steps.	SA2
	Solve problems using a variety of solution strategies.	SA3
	Solve problems using the information obtained.	SA4
	Give justification for the solution steps that have been chosen.	SA5
Reflection and assessment	Presenting the results of group work in various forms of presentation (for example: using PowerPoint)	RA1
	Give feedback on other groups' work shown.	RA2
	Make a reflection in your group.	RA3
	Provide suggestions for improvements and corrections if there are errors.	RA4
	Assess other groups by asking questions.	RA5

Table 3. Considerations in EFA

Consideration	Explanation
Sample size	120 sample
Correlation between items	±0.50
Measures of sampling adequacy	
Kaiser-Mayer-Olkin (KMO)	≥0.50
Bartlett's test of sphericity	<0.05
Anti–image correlation matrix	≥0.50
Communality value	≥0.05
Factor loading value	≥0.50
Eigenvalue	>1
Percentage of variance	≥60%
Parallel analysis	Associated eigenvalue >eigenvalue from random uncorrelated data.

Following the construct validity procedure, the researchers assessed the instrument's reliability to evaluate the questionnaire's internal consistency. Test-retest reliability, inter-rater reliability, parallel-form reliability, and internal consistency reliability are just a few methods for assessing an instrument's reliability [32]. This study used the Cronbach alpha value to examine the instrument's internal consistency reliability. The Cronbach alpha value was determined and compared to the Cronbach alpha values proposed by Bond and Fox [33], as shown in Table 4.

Table 4. Interpretation of Cronbach alpha-score

Cronbach alpha score	Interpretation
<0.5	Items need to be dropped
<0.6	Items need to be repaired
0.6–0.7	Acceptable
0.7–0.8	Good and acceptable
0.8–1.0	Very good and effective level of consistency

4. RESULTS AND DISCUSSION

Kaiser-Meyer-Olkin (KMO) measurement and Bartlett's sampling adequacy test for the sphericity test were used to conduct EFA. The KMO adequacy test showed a value of 0.797, and the sphericity test by Bartlett was found to be significant (X2=3104.135). Communities of the items varied from 0.661 to 0.882. Overall, the results of KMO, Bartlett's test, and communalities value were summarized in Table 5.

Table 5. KMO and Bartlett's test

Test	Results
KMO	0.797
Bartlett's sampling adequacy test	3104.135
df	120
Sig.	0.000
Communalities	0.661–0.882

The researchers proceeded with the EFA process using the PCA approach with varimax rotation based on the KMO and Bartlett's test results to determine the correlation between items. Only items with correlation and factor loading values greater than 0.50 (>0.50) were retained, while those with correlation and factor loading values lower than 0.50 were removed to ensure a high correlation coefficient for the remaining items. Consequently, 10 items were removed from the initial questionnaire. Table 6 depicts the number of items eliminated based on the construct, whereas Table 7 shows the factor loading values for the remaining items. 25 items were retained after the EFA was completed. The researchers measured the instrument's reliability after completing the procedure for factor analysis. As shown in Table 4, the researchers calculated the value of Cronbach's alpha and compared it to the recommended value. The remaining 25 items of this instrument are consistent and efficient, as reflected in the Cronbach alpha value of 0.885.

Table 6. Item distribution after factor analysis

Construct/sub-construct	Numbers of items	The number of items dropped
Group division	5	0
Identifying problems	5	0
Generating ideas	5	2
Learning issue	4	1
Self-directed learning	3	0
Synthesis and application	5	2
Reflection and assessment	5	2
Total	32	7

The EFA and reliability results indicated that the instrument measuring primary school mathematics teachers' perceptions of PBL activities has higher validity and reliability. The validity and reliability of the instrument can be improved by the researchers using these two methods [34]. The EFA approach can improve the validity of an instrument by identifying the underlying structure of a set of variables, their correlations with one another, the factor loadings, and any items that do not significantly load on any factor [35].

Following the EFA procedure, seven items that did not meet the minimum requirements for item acceptance were eliminated. According to Hair *et al*. [26], for a sample size of 120 people, only items with a correlation value and factor loading value exceeding 0.50 are accepted. The researchers guarantees that the items retained are more likely to measure the underlying factor by keeping items with factor loadings greater than 0.5 [36].

In addition, EFA results indicate that this instrument's construct is represented by six factors that were generated for this instrument. These include group division, generating ideas and learning issues, identifying problems, self-directed learning, synthesis and application, and reflection and assessment. There were two factors (generating ideas and learning issues) combined into a single factor. This demonstrated that these six factors are appropriate for measuring primary school mathematics teachers' perceptions of PBL activities. This view is consistent with previous research [37], which stated that an instrument could have high validity even though the number of factors generated does not equal the number of originally employed factors as it has undergone EFA.

Table 7. Factor loading values

Item	Factor loading value (N=120)						Communalities
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	
GD2	0.900						0.852
GD1	0.871						0.788
GD3	0.865						0.822
GD4	0.869						0.767
GD5	0.717						0.805
GI4		0.824					0.791
LI3		0.774					0.800
GI2		0.727					0.720
GI1		0.719					0.815
GI2		0.708					0.753
LI1		0.583					0.661
IP5			0.927				0.882
IP2			0.917				0.871
IP4			0.897				0.854
IP3			0.859				0.770
IP1			0.844				0.754
SA3				0.887			0.832
SA4				0.878			0.882
SA1				0.859			0.849
SL2					0.575		0.821
SL1					0.837		0.745
SL3					0.725		0.709
RA4						0.560	0.879
RA5						0.572	0.878
RA3						0.790	0.725

The study also found that the item counts per construct are sufficient. This study contained sufficient items to assess the subconstructs of learning issues (6 items), identifying problems (5 items), self-directed learning (3 items), synthesis and application (3 items), and reflection and assessment (3 items). According to Yusoff [38], having at least three items per construct can improve the factor's reliability by giving more information about the factor and resulting in more reliable and consistent findings [26]. It would be difficult to understand the factor structure and impossible to get a unique estimate of the factor loadings with less than three items per construct [39].

Other than that, the Cronbach alpha value of this instrument is 0.888. According to Bond and Fox [33], instruments with Cronbach's alpha scores ranging from 0.8 to 1 are reliable and consistent. This suggests that this questionnaire's validity and reliability are high [40]. Hence, this instrument is suitable for evaluating primary school mathematics teachers' perceptions of PBL activities involving group division, generating ideas and learning issues, identifying problems, self-directed learning, synthesis and application, reflection, and assessment. In this regard, this instrument can be used in actual research.

5. CONCLUSION

This exploratory factor analysis seeks to ensure that the instrument developed applies to actual studies. In this light, it is necessary to modify the existing instruments to ensure that all remaining constructs and items meet the minimum requirements. This instrument generates six factors effectively compared to seven factors before the exploratory factor analysis procedure. The factors are group division, generating ideas and learning issues, identifying problems, self-directed learning, synthesis and application, reflection, and assessment. All remaining items in each factor have a factor loading value of at least 0.50, which exceeds the acceptance threshold. This instrument is suitable for real-world research due to its high validity and reliability. For future research, the researchers suggest conducting a confirmatory factor analysis to develop a structural modelling equation model that matches the study data. In conclusion, this study successfully validated an instrument to measure primary school mathematics teachers’ perceptions of PBL activities.

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