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Validity of instrument to measure primary school mathematics teachers' acceptance of m-learning applications

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ABSTRACT

Mobile learning (M-learning) is one of the proposed technology-based methods for teaching mathematics in today's education 4.0 era. This method enables teachers to conduct instruction and learning without being bounded by walls, wires, and the need for specialized physical infrastructure and facilities. This study was conducted to develop and validate an instrument for evaluating primary school mathematics teachers' acceptance of M-learning applications in problem-solving teaching involving six variables. This research is quantitative and utilizes a questionnaire to collect data. This study involved a total of four experts and 120 participants. Cronbach's alpha and Exploratory Factor Analysis were used to perform a descriptive analysis of the data. Cronbach's alpha was determined to be 0.934, with a factor eigenvalue greater than 1. The Kaiser–Meyer–Olkin 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 and a variance of ≥60%. The findings showed that this instrument contains six constructs and nineteen appropriate items. It also indicated that this instrument could be used to investigate perceptions of the primary school mathematics teachers' acceptance of m-learning applications in problem-solving teaching instruments involving performance expectancy, effort expectancy, social influence, facilitating conditions, behavioral intention, and usage behavior (attitude).

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1. INTRODUCTION

The emergence of Industrial Revolution 4.0 (IR 4.0) has accelerated science and technology advancements across the globe. According to Oke and Fernandes [1], this revolution is a state of change and improvement in terms of civilization and human civilization. This revolution involves introducing modern communication, technological application, and information management. Consequently, numerous new technologies exist and affect multiple disciplines.

In this advanced era, teachers are encouraged to utilize technology to enhance the quality of teaching. Scholars have argued the application of technology can improve teachers' pedagogical efficacy. For instance, the evolution of technology helps establish online content systems such as mobile learning (M-learning), which helps create a viable and effective education system [2]. The primary objective of implementing M-learning is to increase student motivation and prepare them for knowledge acquisition. This method encourages teachers and students to explore information from various perspectives and generate numerous new ideas [3]. Studies have found that teachers and students are highly interested in using learning applications that are offered for free, have multiple functions, and are easily accessible [4].

On the other hand, while there are a variety of learning applications available to teachers, the use of technology for teaching problem-solving in mathematics education is still low [5]. Teachers continue to practice one–way communication and only use textbooks as learning resources. This situation should not happen in our education system as it does not fulfill students' need for collaborative, interactive, and hands-on learning [6].

Practices in mathematics education must change to cater to students' needs in the 21st century. Saldivar *et al.* [7] believed that the education system must be reevaluated to ensure students' learning aligns with global educational needs. These adjustments must be made so the current student generation can keep pace with technological advancement. Consequently, all educational institutions, including schools, must embrace instructional technology [8], including M-learning.

Ultimately, it is necessary to determine the level of primary school mathematics teachers' acceptance of adopting M-learning in teaching mathematics problem-solving. This study was conducted to develop and validate an appropriate instrument to determine the level of primary school mathematics teachers' acceptance of M-learning in teaching problem-solving. In this light, a researcher can conduct the relevant study by creating and administering a suitable instrument.

2. LITERATURE REVIEW

According to previous studies [9], [10], teachers are highly prepared to implement mobile learning (M-learning). This is because they possess the necessary resources and expertise to implement the teaching method. These studies demonstrated that teachers positively perceive M-learning in developing students who excel in various skills, including technology-related skills, knowledge, competitiveness, and competence.

On the other hand, Ndilimeke and Shawulu [11] revealed that Polytechnic lecturers have a low level of knowledge and a moderate level of skill in implementing M-learning teaching methods. While this study's findings differ from others regarding the knowledge and abilities required to implement M-learning, it presents significant input regarding teachers' readiness and attitude toward the teaching method. The understanding of such readiness would inform a decision on the integration of M-learning in teaching and learning and likely serve as a reference to other higher institutions of learning [12].

A survey by Selvy *et al.* [13] revealed that M-learning has considerable potential for implementation in Malaysia. The study found that teachers can use the learning applications available on mobile devices and develop various interactive learning applications. These applications allow teachers to implement self-learning strategies and flexible teaching implementation. Furthermore, they provide opportunities for students to explore learning within the allotted time [14].

In the context of secondary education, Kaviza [15] demonstrated that students have a moderate perception regarding M-learning implementation through Google Classroom. The findings of this study differ from another study [16], which found that using an interactive learning application involving symbols in the Hadith lesson increased students' motivation, knowledge, and ability to comprehend the arrangement of sanad through the diagrams presented in the application.

Similarly, Mambu *et al.* [17] developed an Android 3D Math application for learning three-dimensional geometry. The study found that it has increased students' mathematical achievement and interest. During this study, the treatment group students demonstrated differences in attitude, motivation, behavior, and response from those in the control group.

Based on the studies mentioned, M-learning research in Malaysia has mainly focused on the readiness and acceptance of users toward implementing this method, as well as creating mobile learning applications that various parties can utilize involving secondary education, colleges, and universities. This demonstrates that research has not yet been conducted at the primary level and creates a gap to be filled. So, this study was undertaken to develop and validate the appropriate instruments that can be used to determine the level of acceptance of M-learning in teaching problem-solving by primary school mathematics teachers.

3. RESEARCH METHOD

This study was conducted using a survey method. This method is appropriate for assessing large populations' perceptions, opinions, and beliefs [18]. A sample of 120 primary school mathematics teachers was chosen for the study. The selection numbers for the sample are based on the loading factor value from Hair, Babin, and Anderson [19], which is 0.50 for a sample of 120 people.

The researchers used questionnaires in this study because the sample size was large and comprehensive [17]. This instrument was developed by the researcher based on The Unified Theory of Acceptance and Use of Technology (UTAUT) Model [20], as shown in Figure 1. This instrument consists of

29 items to measure the construct of acceptance of M-learning applications in problem-solving instruction, as shown in Table 1, and the item specifications for each sub-construct are provided in Table 2.

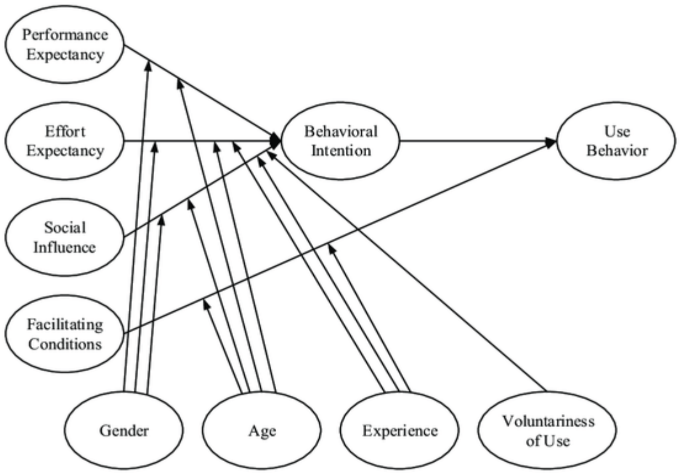

Figure 1. The Unified Theory of Acceptance and Use of Technology model

Table 1. Details of questions item

Part	Construct/Sub-construct	Numbers of items
Part A	Demography	
Part B	Acceptance of M-learning	
	Performance expectancy	5
	Effort expectancy	5
	Social influence	5
	Facilitating conditions	4
	Behavioral intention	5
	Use behavior (attitude)	5
	Total	29

Table 2. Details of questions item based on construct

Sub-construct	Item	
Performance expectancy	Developing constructivist teaching.	PE1
	Improve the quality of teaching.	PE2
	Encourage exploration among students.	PE3
	Create a student-centered learning environment.	PE4
	Diversify teaching methods.	PE5
Effort expectancy	Makes it easier for me to choose effective learning materials.	EE1
	Help me to build effective learning materials.	EE2
	Facilitate my interaction with students.	EE3
	Simplify the teaching and learning process.	EE4
	Make me efficient in using learning applications (Example: Google Classroom)	EE5
Social influence	The students encouraged me to share information through applications available on mobile devices.	SI1
	My colleagues encouraged me to do it.	SI2
	The school administrators gave me support to implement it.	SI3
	The Ministry of Education encourages teachers to integrate ICT into teaching.	SI4
	World education encourages teachers to implement teaching without being limited to the classroom.	SI5
Facilitating conditions	Allowing students to bring mobile devices to school for learning purposes.	FC1
	Providing internet access facilities for learning purposes.	FC2
	Provide special room facilities for learning purposes.	FC3
	Providing mobile device facilities to teachers for teaching purposes (Example: laptop).	FC4
Behavioral intention	To be used for teaching mathematics in the present and the future.	BI1
	To be used for teaching all topics and skills in mathematics education.	BI2
	As a tool for sharing information before learning is carried out.	BI3
	As a tool for evaluating student achievement after the end of the learning session.	BI4
	As a form of additional training during school holidays.	BI5
Use behavior (attitude)	Help me diversify my teaching methods.	UB1
	Help shape my positive perception towards ICT-assisted teaching.	UB2
	Help me to create learning materials according to the students' abilities.	UB3
	Help me assign assignments if I need to attend workshops outside school.	UB4
	Creating a learning environment that is not limited to classroom space.	UB5

A 5-point Likert scale was used in the instrument to evaluate the variables in this study. This pilot study's data were analyzed using IBM for SPSS Version 20. Face, content, and construct validity were determined to warrant that the instrument developed addresses the issues under study and that the data obtained reflect the study's findings [20].

To conduct the face and content validity procedures, selecting the experts' number has always been partially arbitrary [21]. To have adequate control over the chance agreement, it is advised that a study must involve a minimum of three experts in determining the content validity index [22]. To that, there were four experts in Malay studies, curriculum, mathematics education, and assessment and evaluation were appointed to conduct the face and content validity procedures.

This group of experts must determine whether: i) the proposed items are appropriate; ii) the number of items is sufficient; iii) correct language, sentence structure, and terminology are used; and iv) the 5-point scale can be used to evaluate the items. Based on the expert review, six items were removed from the sub-constructs of effort expectancy, social influence, behavioral intention, usage behavior (attitude), performance expectancy, and facilitating conditions. As a result, out of the 35 items in the initial questionnaire, only 29 were retained as shown in Table 1.

Subsequently, the researcher performed an Exploratory Factor Analysis (EFA) to determine the instrument's construct validity. This statistical technique is used to identify underlying factors or dimensions in a set of variables [23]. It is often used in the social sciences, such as psychology, sociology, and education, to explore the structure of a large number of variables and to identify patterns or relationships among them [24]. It is a useful tool for reducing large dataset's complexity and identifying the most critical variables in a study.

This method was executed using data from the pilot study. In this study, this procedure guarantees that each sub-construct item is adequate and suitable for measuring the specified constructs [19]. This procedure was conducted based on three primary considerations: sample size, correlation matrix, and sampling adequacy. As shown in Table 3, numerous tests have been conducted for sampling adequacy to determine the sample's adequacy and the data suitability [25].

This study used Principal Component Analysis (PCA) with varimax rotation to ensure that each item within each sub-construct is discernible [19]. In addition, parallel analysis methods were used to determine the number of factors that needed to be eliminated or maintained [26]. In contrast, the eigenvalue was employed to determine the number of factors required in the instrument.

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

The researcher examined the instrument's reliability after determining the construct validity. The test was performed to determine the internal consistency of the instrument. It is a statistical measure of the correlation between all items on the instrument. A high alpha value indicates that the items are highly correlated, and therefore, the instrument has a high level of internal consistency reliability [27]. To that, the Alpha Cronbach value was calculated and compared to the Alpha Cronbach values proposed by Bond and Fox [28], 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

Varimax rotation was used with Principal Component Analysis (PCA) to determine the correlation between items and sampling adequacy. The Kaiser- Mayer Olkin (KMO) provided a value of 0.703, suggesting that the sample measurements were sufficiently large to calculate the factor structure. The sphericity test by Bartlett, a measure of the relation intensity between variables, confirmed the appropriateness of factor analysis. The data obtained after completing the procedure are shown in Table 5.

Table 5. Correlation's value between items and sampling adequacy

Consideration	Actual values
Correlation between items	All items have a correlation value ≥ 0.50
Measures of sampling adequacy	
Kaiser-Mayer Olkin (KMO)	0.703
Bartlett's test of sphericity	0.000
Anti–image correlation matrix	0.508 – 0.813
Communality value	0.476 – 0.922
Factor loading value	0.673 – 0.955
Eigenvalue	1.029 – 4.772
Percentage of variance	75.620%
Parallel analysis	6 factors

The researcher analyzed the correlation values between items and the loading factor values to determine which items were appropriate. The researcher selects items with correlation and factor loading values exceeding 0.50 (>0.50). This item was discarded for items with a low value. This item's removal guarantees that each remaining item has a high correlation coefficient with the others. Therefore, 10 items were removed from this instrument. Table 6 depicts the number of items eliminated based on the construct, while Table 7 displays the factor loading values for the remaining items. Following the completion of the exploratory factor analysis, 19 items remained.

Table 6. Item distribution after factor analysis

Part	Construct/Sub-construct	Numbers of items	The number of items dropped
Part A	Demography	5	0
Part B	Acceptance of M-learning		
	Performance expectancy	5	1
	Effort expectancy	5	2
	Social influence	5	2
	Facilitating conditions	4	1
	Behavioral intention	5	2
	Use behavior (attitude)	5	2
	Total	29	10

Table 7. Factor loading values

Item	Factor loading value (N=120)						Communalities
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	
PE3	0.917						0.898
PE5	0.916						0.907
PE2	0.916						0.895
PE1	0.912						0.891
UB4		0.955					0.921
UB3		0.953					0.922
UB5		0.916					0.851
EE3			0.904				0.871
EE4			0.890				0.897
EE2			0.883				0.893
BI3				0.801			0.789
BI1				0.626			0.476
BI4				0.541			0.482
FC2					0.805		0.698
FC4					0.696		0.547
FC3					0.577		0.690
SI3						0.521	0.515
S14						0.797	0.709
SI5						0.673	0.515

Following the procedure for factor analysis, the researcher conducted the procedure for measuring instrument reliability. The researcher has calculated the value of Cronbach's alpha and compared it to the recommended value, as shown in Table 4. The other 19 remaining items of this instrument are consistent and effective as a whole, as shown in the Cronbach alpha value of 0.821.

5. DISCUSSION

Exploratory Factor Analysis results indicated that the instrument for measuring primary school mathematics teachers' acceptance of M-learning applications in problem-solving teaching is highly valid. Following the exploratory factor analysis procedure, 10 items were eliminated for failing to meet the minimum requirements for item acceptance. According to Hair, Babin, and Anderson [19], only items with a correlation value and factor loading value exceeding 0.50 are accepted for a sample size of 120 people. Correlation and factor loading values exceeding 0.50 indicate a strong association between the observed variable and the factor. This means that the observed variable was highly related to the factors, and the variable's variance can be explained to a large extent by the factor [29].

The exploratory factor analysis results further indicated that the instrument's constructs represent the six factors for which this factor was generated. The factors are effort expectancy, social influence, behavioral intention, usage behavior (attitude), performance expectancy, and facilitating conditions. This demonstrates that these six factors are appropriate for measuring the perceptions of primary school mathematics teachers regarding the acceptance of M-learning applications in problem-solving teaching. This perspective is consistent with previous research [30] which stated that an instrument has a high validity when the number of factors generated equals the number of factors originally used. Meanwhile, Santos *et al.* [31] stated that if the number of factors generated matches the number of factors used initially, it suggests that the instrument can identify the underlying structure of the construct as intended.

In addition, the item counts per construct are adequate. There are enough items in this study to measure subconstructs of performance expectancy (4 items), effort expectancy (3 items), social influence (3 items), facilitating conditions (3 items), behavioral intention (3 items), and usage behavior (attitude) (3 items). In factor analysis, it is commonly recommended that each construct or factor should have at least 3 items [32]. This is because factor analysis is a statistical technique based on the variables' correlation matrix. Having at most 3 items per factor may make it easier to estimate the factor structure reliably [33]. According to Gaskin and Happell [34], a common practice is to have at least 3 to 5 items per factor, depending on the sample size and the complexity of the measured construct.

Furthermore, the alpha Cronbach value for this instrument is 0.93. Cronbach's alpha is a statistic used to assess the internal consistency or reliability of a measure or scale. It is a coefficient ranging from 0 to 1, with a higher value indicating better internal consistency [35]. Alpha is calculated by analyzing the correlation between all the items on a scale and averaging them. Meyers, Gamst, and Guarino [36] stated that instruments with alpha Cronbach's scores between 0.8 and 1 are reliable and consistent. Besides, Bro and Smilde [37] also stated that an alpha value of 0.8 or higher is considered good, and a value of 0.9 or higher is considered excellent. This indicates that this questionnaire's validity and reliability are high. Therefore, this instrument is appropriate for evaluating the perception of primary school mathematics teachers' acceptance of M-learning applications in problem-solving teaching involving performance expectancy, effort expectancy, social influence, facilitating conditions, behavioral intention, and usage behavior (attitude). Afterward, it is proposed that this instrument be utilized in actual studies regarding the level of performance expectancy, effort expectancy, social influence, facilitating conditions, behavioral intention, and user behavior (attitude).

6. CONCLUSION

This Exploratory Factor Analysis (EFA) aims to ensure that the instrument developed is applicable to actual studies. It is necessary to modify the existing instruments to ensure that all remaining constructs and items satisfy the minimum requirements. According to factor analysis, this instrument generates six factors effectively: effort expectancy, social influence, behavioral intention, usage behavior (attitude), performance expectancy, and facilitating conditions. The study found that the number of generated factors equals the number of constructs in the original instrument. Furthermore, all remaining items in each factor have a factor loading value of at least 0.50, which is the minimum requirement for item acceptance.

The researchers recommend conducting a Confirmatory Factor Analysis (CFA) for future research. CFA is a statistical technique used to evaluate the factor structure of a set of observed variables and assess how well they measure a latent construct. In CFA, a hypothesized factor structure is tested against the data using a variety of fit indices to determine the model's goodness of fit. CFA aims to determine if the observed variables are measuring the same underlying construct and to identify any measurement errors in the data.

CFA can also be used to compare different factor structures and select the best-fitting model to develop a SEM model that matches the study data. Overall, this study successfully validated an instrument to measure primary school mathematics teachers' perceptions of M-learning applications for teaching mathematics problem-solving based on factors including effort expectancy, social influence, behavioral intention, usage behavior (attitude), performance expectancy, and facilitating conditions. Due to its high reliability, this instrument is suitable for real-world research investigating the level of acceptance and preparation for M-learning among Malaysian primary school mathematics teachers.

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