The Validity of Ethnomathematics-Augmented Reality Instructional Materials on Scale and Proportion

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Abstract. Mathematics is a human activity. Therefore, the learning process should start in a context close to the students, such as a culture-based mathematics context, commonly referred to as ethnomathematics. Furthermore, technology-based (e.g., augmented reality) media plays a pivotal role in assisting students in constructing a mathematical concept. However, there were limited studies on technology-based instructional materials using the ethnomathematical context of Aceh, Indonesia, especially on scale and proportion. This study aims to determine the validity of ethnomathematics-augmented reality instructional materials on scale and proportion. This study was part of developmental research using the Plomp and Nieveen model. The data in this study were collected through instructional materials validation sheets from six experts. The validity test result showed that the materials developed reached valid criteria with an average score of 4.7 out of 5. The comments and suggestions from the experts were discussed in this study. This result implies that the ethnomathematics-augmented reality instructional materials on scale and proportion could be used for the next stage of development.

Keywords: Augmented Reality, Ethnomathematics, Module, Scale and Proportion, Validity.

1 Introduction

Mathematics plays a major role in the development of science and technology; it could be implemented as a tool in other disciplines and in the development of mathematics itself [1]. Therefore, in this era of competitiveness, students' understanding of mathematical subjects is essential.

Mathematics could be taught effectively and meaningfully by linking it to culture [2]. Students enjoy mathematics more after learning the material from a cultural perspective [3]. The approach to bridge the gap between mathematics and culture is called ethnomathematics. Ethnomathematics can be defined as mathematics practiced by national or specific community groups [4]. This implies that ethnomathematics is a science applied to understand how mathematics is adapted from culture and may be used to link the relationship between culture and mathematics found in various communities.

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The mathematical concepts are delivered in a cultural context through ethnomathematics-based mathematics learning. The advantage of cultural context is the potential that applies to all regions. One of the cultural contexts used in this study was Indrapatra Fort, located in Aceh Besar, the first fort of the Hindu kingdom. Based on the historical records, Putra Raja Harsa built this fort during the Lamuri kingdom in the 7th century AD. During the reign of Sultan Iskandar Muda, Admiral Malahayati utilized the fort to defend the kingdom of Aceh Darussalam from various attacks coming from the Malacca Strait; this fort became a witness to Aceh's transition from the peak of Hindu glory to the rise of Islamic age [5]. As the context presented is the history of the Aceh region, it is hoped that teachers can use it as an interesting teaching resource for students to follow the learning efficiently.

With the advancement of technology, the incorporation of Augmented Reality (AR) in education is on the rise, offering new possibilities in teaching and learning. AR, a mixed-reality technology, integrates virtual objects into the real world to simplify complex information [6]. The application of AR in learning facilitates teachers in presenting instructional materials more effectively, reducing the time required and providing students with novel experiences within a digitally enriched learning environment [7]. In this study, the use of AR will greatly assist students in imagining directly the shape of the Indrapatra Fort and can clarify the geometric features inherent in the fort's structure.

In Indonesia, many teachers commonly employ direct learning, characterized by a teacher-centered approach in classroom activities. Consequently, students often find themselves less fully engaged in their studies. To enhance student involvement in problem-solving that integrates knowledge and skills, teachers are encouraged to adopt cooperative learning methods, such as the Project-Based Learning (PjBL) model [8].

Several studies have been conducted in order to assess the validity of ethnomathematics-based instructional materials, Augmented Reality-based instructional materials, and PjBL-based instructional materials. The previous studies showed that the instructional materials developed were valid and feasible to use with minor revisions. It could be an alternative for teachers to overcome students' difficulties in understanding mathematics and culture and foster students' interest in learning because the learning used virtual technology that was close to students' daily lives [9], [10]. Furthermore, the other study showed that, with an excellent category of teacher's ability and a good category of students' activity (average scores of 89.5% and 81.4%, respectively), the PjBL model in mathematics learning might effectively stimulate student involvement in learning [8].

Despite the results of previous studies, there were limited studies reported about the validity of AR-based instructional materials using the Indrapatra Fort context, especially on the topic of scale and proportion. Meanwhile, understanding the concept of scale and proportion is important because it is widely used in daily life and other sciences, such as to design a building blueprint, building replica, and map [11]. Therefore, this study aimed to describe the validity of ethnomathematics Augmented Reality-based mathematics instructional materials on scale and proportion. The materials developed included a teaching module, student worksheet, and learning outcome test.

2 Methods

This research used Plomp and Nieveen's research and development model, consisting of three development stages: initial investigation, prototyping, and assessment [12]. However, the researchers only focus on the prototyping and assessment stages in this study.

The subjects of this study were validators and junior high school students. Six validators were involved in this study: four (V1, V2, V3, and V4) were mathematics education lecturers, and the other two (V5 and V6) were junior high school mathematics teachers. Furthermore, the students who participated in this study were 10 students from one junior high school in Banda Aceh, Indonesia.

The data in this study was collected using validation and readability sheets. The average score of validators' assessments was used to determine the validity criteria. The validity criteria [13] can be seen in Table 1.

Table 1. Validity criteria of instructional materials.

Criteria	Averages
Strongly Valid	$4 < VC < 5$
Valid	$3 < VC < 4$
Less Valid	$2 < VC < 1$
Invalid	$1 < VC < 2$

The developed ethnomathematics-augmented reality instructional materials on the scale and proportion were valid. They could be continued to the next stage of development if the result of validators' assessments is at least in the valid criteria. The readability test was then conducted to assess whether respondents could easily read and understand the student worksheet and learning outcome test.

3 Results and Discussions

The results of this study include the validity of ethnomathematics-AR instructional materials on scale and proportion. These materials will later be used for application in mathematics learning, which aims to increase students' positive responses and foster students' interest and motivation in learning mathematics. The results of the validation of the instructional materials by validators are presented in Table 2.

Table 2. Results of instructional materials validation.

No	Instructional Materials	Aspects Assessed	Results of Validators' Assessment						Average	Average Validation	Criteria
			V1	V2	V3	V4	V5	V6			
1	Teaching Module	Contents	4.8	4.8	4.6	4.4	4.4	4.8	4.6	4.5	Strongly Valid
		Language	4.6	4.6	4.6	4.6	4.6	4.3	4		

2	Teaching Worksheet	Contents	4.8	4.8	4.6	4.4	4.4	4.8	4.6	4.7	Strongly Valid
		Language	4.6	4.6	4.6	4.6	4.6	4.3	4		
3	Learning Outcome	Contents	4.5	4.7	5	4.7	4.5	4.5	4.7	3.6	Valid
		Language	4.6	4.3	4.6	4.3	4.5	4.5	4.6		
		Construct	-	-	3.8	-	3	3	3.2		
		Social Culture	-	-	3.2	-	3	3	3		

Table 2 illustrates that the average score of validation result for the teaching module is 4.5; thus, it met the strongly valid criteria for both contents and language aspects. Furthermore, the developed student worksheet also met strongly valid criteria, with an average score of 4. Therefore, the teaching module and student worksheet could be used for the next stages of development after minor revisions. Furthermore, overall, the developed learning outcome test achieved an average score 3.6 from the validators. The learning outcome test met the valid criteria and could be used for the next developmental stages after minor revisions.

The validators also suggested improving the ethnomathematics-AR instructional materials on scale and proportion. The detailed explanation of revisions will be described as follows.

3.1 Revisions on the Teaching Module

The validation results obtained from the teaching module in the form of suggestions and comments given by the validator to the researchers include that the learning in the teaching module should be centered on students, the format of the teaching module developed must refer to the curriculum policy implemented, and the activities in the teaching module must be adjusted and need to be detailed. Table 3 presents all validator suggestions and comments on the teaching module and the revised results.

Table 3. Results and validators comments on the teaching module.

Validator	Comments and Suggestions	Corrections Made
Validator 1	In the teaching module meeting 1, the learning contained in the teaching module is not all learner-centered.	All activities contained in the teaching module are learner-centered.
	In the teaching module for meeting 2, the instructions are not aligned with the student worksheet.	The commands in the teaching module have been adapted to the student worksheet.
	In teaching module meeting 2, examples of the application of scale and proportion in everyday life should be given pictures because students tend to like pictures.	Examples of the application of scale and proportion in daily life in the teaching module have been changed with pictures.
Validator 2	In the meaningful understanding section, the statements of visit route design and miniature design should be separated to avoid double meanings.	The statement on designing visit routes has been separated from the statement on designing miniatures.

	In teaching module meeting 1, the questions listed in the questioning section do not match the instructions.	Questions have been adapted to the instructions contained in the teaching module.
Validator 3	In teaching module meeting 1, cardinal directions applied to learners need a real-world perspective, not just computer visuals.	The cardinal directions in the teaching module have been adjusted to the cardinal directions in the real-world perspective.
	In teaching module meeting 1, images and narration on the route need a starting point.	The starting point of the narrative story has been given in the student worksheet instructions.
Validator 4	ATP (Indonesia's abbreviation for route of learning objectives) needs to be added to the learning outcomes.	The learning outcomes have been adjusted to the curriculum policy implemented by the government.
	The formulation of learning objectives lacked a "degree" or a target should be achieved by students.	The learning objectives have been adapted to the curriculum policy implemented by the government.
Validator 5	The teaching module as a whole is good and can be used; the moral message for each meeting should be adjusted to the context applied.	Moral messages for all meetings have been adapted to the context applied.
Validator 6	The teaching module design is good, but the instructions and directions contained in the teaching module need to be adjusted.	The instructions and directions on the teaching module have been adjusted.

As presented in Table 3, one comment of the validator was to revise and adjust the instructions and directions in the teaching module. Thus, the researchers had modified the instructions because this is in line with Daryanto and Dwicahyono [14] stated that the language used in lesson plan must be clear so that it does not cause multiple interpretations and other teachers could use it without confusion.

3.2 Revisions on the Student Worksheet

The suggestions and comments given by V1, V2, V3, V4, V5, and V6 are that the student worksheet is wordy, and the activities in the student worksheet should be clarified and adjusted. Table 4 provides the detailed suggestions and comments from the validators.

Table 4. Results and validators comments on the student worksheet.

Validator	Comments and Suggestions	Corrections Made
Validator 1	In the essential question section, the story of the building of Fort Indrapatra should be illustrated by pictures and not use too many sentences.	The story of the fort has been replaced with a picture.
	When describing the route of the visit, learners should be asked to determine the distance between objects first.	A command to find the distance between objects has been added.
	The commands contained in the student activity when designing the miniature of the main fort	The command to design a miniature of the main fort has been replaced by designing a

	should be limited because it will take a long time to work on it.	tubular and hemispherical miniature of the main fort.
Validator 2	The instructions in the student activity should be clarified in detail if necessary, and the objects in the picture should be pinned or made clear to the naked eye.	Object images have been clarified.
Validator 3	The story in the visit route generation narrative should be given a starting point.	The narrative story on the visit route has been given a starting point.
Validator 4	The demonstration instructed to learners should be complete, not just at the beginning. The instructions at the beginning of the activity are good if, in the assignment section, you are asked to describe the route and provide more detailed instructions.	The instructions have been adjusted to the instructions given on the student worksheet. The commands on the assignment have been given detailed instructions.
Validator 5	The word "in" should not be given at the beginning of the sentence.	The words have been changed according to the suggestions and comments provided.
Validator 6	In the assessment phase, in the color section of the product produced by students, subjective questions should be replaced with objective questions.	The questions contained in the assessment phase have been adjusted.

The validators' suggestions are consistent with Prastowo's [15] argument that the activities in the student worksheet must be easy to read and understand, and the layout design of the student worksheet must be appealing.

3.3 Revisions on the Learning Outcome Test

According to V3, V4, and V5, the learning outcome test needs to be adjusted and clarified. The problem boundaries must be adjusted and the problems need to be formulated clearly. All validator comments and suggestions on the test, and the revision results are presented in Table 5.

Table 5. Results and validators comments on the test.

Validator	Comments and Suggestions	Corrections Made
Validator 3	Questions should be clarified and typo-checked.	Questions have been revised and clarified.
Validator 5	The picture attached to the question can be scaled down to clarify the object.	The attached image has been zoomed in.
Validator 6	The question must be clarified whether it is the actual distance or the distance on the map. If the actual distance that is asked, then provide the original data related to the scale attached to the test item to match.	The questions have been revised according to the validator's suggestions.

The suggestions and comments given by the validators have been incorporated. Hence, the AR-assisted ethnomathematics-based mathematics learning tool on the scale and proportion material developed meets the criteria for being very valid and is feasible to use. The teaching modules and student worksheets designed follow the PjBL learning

stages because they use contextual problems where students must investigate and actively participate in learning to increase high motivation for students with quality project results [16]. Thus, in the process of completing projects, students can find mathematical concepts in culture, and students become more familiar with sharing cultural heritage related to mathematics.

Meanwhile, the test items developed satisfied the very valid criteria. However, there were some suggestions and comments by the validator. However, the test developed can be used with minor revisions, and the researchers have revised it accordingly.

Student worksheet and the test that have been validated were then tested for readability by ten students in one of the secondary schools in Banda Aceh. Based on the analysis conducted by the researchers on the students' responses, Table 6 presents the students' suggestions and comments.

Table 6. Results of the student worksheet readability test on students.

Student worksheet readability test	Corrections Made
Learners do not understand the language in the student worksheet, such as the words "respected" and "silent witness." In addition, there is also an error in writing "kerajaan".	The researchers revised the word "Karajan" to "kingdom." In addition, the researchers no longer revised the word "respected" because the researcher explained the meaning of "respected" directly to the students. Meanwhile, the researchers deleted the word "mute witness" in the sentence of the paragraph.
Learners do not understand the language in the student worksheet, such as the words "complex," "site," "cultural heritage," "guided," and "related."	The researchers did not revise the words "complex," "site," "cultural heritage," "guided," and "related" because the researcher explained the meaning of these words directly to the students.
Learners do not understand the meaning of "cardinal orientation game (spatial orientation)" and "information board."	The researchers deleted the words "spatial orientation," but the words "cardinal direction orientation game" and "information board" were not revised again because the researchers explained the meaning of these words directly to the learners.
The image of Fort Indrapatra seen through Google Earth on the student worksheet is not very clear, and it does not understand the position of the Fort Indrapatra object.	The researchers clarified the image of Fort Indrapatra seen through Google Earth on the student worksheet by brightening the contrast of the image to make it brighter. While determining the position of the Indrapatra Fort object, the researcher added the sentence "a building with a well with a dome that has collapsed," the researcher also explained directly to the students the meaning of the object's position.
Learners do not know the meaning of the word "narration."	The researchers did not revise the word "narration" because the researcher explained the meaning of the word directly to the learners.
Learners lack understanding about the visit route in the Indrapatra Fort area.	The researchers explained to the students the purpose of the Indrapatra Fort visit route narrative. In addition, the researcher also did not determine the extent of the direction

	of the visit route because the researcher asked students to determine the direction of the Indrapatra Fort visit route themselves.

Based on the suggestions and responses given by the ten students, the researchers concluded that the student worksheet developed could be understood well. Then, the researchers revised the student worksheet according to the suggestions and comments given by the students. Students' responses and suggestions for the test are provided in Table 7.

Table 7. Results of the test items readability test on students.

Readability test of the test items	Corrections Made
Learners do not understand the cardinal directions on the map.	The researchers did not revise the cardinal directions listed in the question because the researcher explained the details of the cardinal directions directly to the students.
Learners had difficulty looking at the picture attached to the question because the scale was too large.	The researcher clarified the image maps contained in the problem.
Learners do not understand what the word "narration" means.	The researchers did not revise the word "narration" because the researcher explained the meaning of the word directly to the students.
Learners do not know the object to be traveled in the problem.	The researchers have revised the object that is the starting point and the destination to be traveled, which is pinned and boxed to make the position on the map visible.
A typo in the initial object specified "love cottage boarding house"	The typo has been changed to "image."

Based on comments and suggestions from students, the researchers concluded that the test items developed could be understood well. It was just that there were several sentences or words, so students had difficulty understanding the test items. Thus, the researchers revised the test items. Based on the validation results from validators and the readability test results on ten students, AR-assisted ethnomathematics-based mathematics learning tools on scale and proportion materials can be considered very valid for all learning tools developed.

4 Conclusion

This study concludes that the AR-assisted ethnomathematics-based learning tools on scale and proportion materials (teaching modules, student worksheet, and test) have met the criteria of reliability. They are suitable for use with minor revisions. However, AR-assisted ethnomathematics learning tools on scale and proportion materials need to be tested for practicality and effectiveness in learning.

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