

Ethnomathematics-Based Evaluation Instrument to Measure Students' Problem-Solving Ability

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ABSTRACT

This study aims to develop an evaluation instrument to assess students' mathematical problem-solving abilities in an ethnomathematics context, focusing on polyhedra (three-dimensional shapes with flat faces). The research employed a development methodology based on the ADDIE model and involved 29 ninth-grade students. The Analysis phase included identifying needs, reviewing the curriculum, examining student characteristics, and determining learning objectives. In the Design phase, the instrument was constructed by integrating relevant elements of ethnomathematics. The Development phase consisted of expert validation by material and evaluation specialists, followed by individual and small-group trials. The Implementation phase involved a large-group field test, while the Evaluation phase was carried out throughout all stages of the process. The results indicate that the developed instrument is valid (average expert validation score: 85.52%), practical (practicality score: 89%), and effective (effectiveness score: 86.6%). Therefore, the ethnomathematics-based evaluation instrument is effective for assessing students' mathematical problem-solving abilities during the learning process.

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1. INTRODUCTION

Mathematics is often viewed as an abstract discipline that is distant from real-life contexts, even though historically it emerged from human efforts to understand everyday phenomena, which are also reflected in the cultural diversity of Indonesia, including Jambi [1]. This connection between mathematics and culture highlights the importance of presenting meaningful learning experiences that are close to students' daily lives. Implementing learning that links mathematical concepts to real-life situations requires well-planned, structured instruction to ensure the learning process runs effectively [2].

Therefore, to ensure that the learning process aligns with the intended plans and objectives, an appropriate assessment or evaluation instrument is needed.

According to Idrus [3], evaluation provides objective information on students' understanding of the material delivered and serves as a basis for teachers to assess the effectiveness of the learning strategies used. Without evaluation, it becomes difficult for educators and institutions to implement appropriate improvements to the learning process [4]. In mathematics education, evaluation not only measures conceptual understanding but also assesses procedural skills and problem-solving abilities, which are the main goals of mathematics learning [5]. Mathematics learning also emphasizes strengthening skills that encourage students to apply problem-solving abilities in various real-life situations [6]. Therefore, assessment is an essential means of determining the extent to which students have mastered problem-solving abilities.

Based on field observations, mathematics teachers still conduct evaluations that primarily measure conceptual understanding and rarely use problems grounded in real-life contexts. The problems used are generally taken from textbooks and worksheets, and therefore are not designed in accordance with indicators of problem-solving ability. The evaluation instruments used also tend to be limited to tests and do not involve non-test instruments. In addition, teachers have not integrated ethnomathematics into the learning process due to difficulties in its implementation, indicating the need for developing a culturally contextual evaluation instrument.

Previous studies have shown that researchers developed a test instrument to measure students' problem-solving abilities in social arithmetic. However, the instrument developed in that study was not based on ethnomathematics and relied solely on test-based evaluation. Therefore, the development of a contextual mathematics evaluation instrument grounded in ethnomathematics is considered an appropriate approach to measuring students' problem-solving abilities [7].

The development of evaluation instruments that incorporate local culture is important because it helps students understand mathematical concepts through examples that are closely connected to their daily lives [8]. Teachers also need instruments that assess not only conceptual understanding but also students' problem-solving abilities [9]. By integrating ethnomathematics, evaluation instruments can provide a clearer picture of students' abilities and make the learning process more relevant and meaningful. Indonesia has a wide range of cultural elements that can be explored to provide contextual mathematics learning, including the cultural heritage of the Jambi region [10]. This study aims to develop a valid, practical, and effective contextual ethnomathematics-based evaluation instrument to measure students' problem-solving abilities.

2. METHOD

2.1 Type of Research

In developing an evaluation instrument, this study employed a Research and Development (R&D) approach. The ADDIE development model was used, consisting of five stages: Analysis, Design, Development, Implementation, and Evaluation [11]. The ADDIE model is considered appropriate because it provides systematic, well-structured

phases, making it easier for researchers to design new products or refine existing ones to be more practical, comprehensive, effective, and feasible for use.

The ADDIE model in this study was carried out through five systematic stages. The Analysis stage included an evaluation instrument, need analysis, curriculum analysis, learner characteristics analysis, and material analysis. The Design stage involved conceptualizing the evaluation instrument, preparing the storyboard, and designing the research instrument. The Development stage focused on developing the contextual ethnomathematics-based evaluation instrument, conducting expert validation in content and evaluation, and making revisions based on the validators' feedback. Individual trials and small-group trials were conducted to assess the practicality of the evaluation instrument. The Implementation stage was conducted through a large-group trial to assess the product's effectiveness in the learning process. The Evaluation stage was conducted to examine the overall quality of the developed product and to revise it if any shortcomings remained.

2.2 Research Subjects

This study was conducted at SMPN 9 Jambi City and involved students from classes IX A and IX B. The criteria for the research subjects were as follows: in the individual trial, the subject was one ninth-grade mathematics teacher; in the small-group trial, the subjects were nine students from class IX A representing low, medium, and high ability levels; and in the large-group trial, the study involved 29 students from class IX B.

2.3 Data Collection Instruments

The instruments used in the product testing stage consisted of a material expert validation questionnaire, an evaluation expert validation questionnaire, a practicality questionnaire used in the individual and small-group trials, and an effectiveness questionnaire used in the large-group trial. These three types of instruments were used to collect data on the quality, feasibility, and effectiveness of the developed product. The evaluation instrument focused on flat-sided three-dimensional shapes.

The evaluation instrument was prepared based on indicators of problem-solving ability. The guidelines for problem-solving ability indicators were adapted from Polya [12], as presented in Table 1.

Table 1. Indicators of Problem-Solving Ability

Number of Indicators	Indicators of Problem-Solving Ability
1	Ability to Understand the Problem
2	Ability to Develop a Problem-Solving Plan
3	Ability to Carry Out the Plan
4	Ability to Review the Answer

Adapted based on [12]

Table 1 presents the indicators of problem-solving ability that serve as the basis for developing the evaluation instrument. These indicators include four main aspects, namely the ability to understand the problem, the ability to plan the solution, the ability to carry out

the plan, and the ability to review the answer. These four indicators serve as a reference for determining the problem-solving abilities to be measured in the evaluation instrument.

2.4 Data Analysis Techniques

The data analysis techniques in this study encompass three main components. Validity analysis was conducted using expert judgment to assess the instrument's feasibility in terms of both content and evaluation. Practicality analysis was obtained from teacher and student response questionnaires during the trial phase. Furthermore, effectiveness analysis was carried out by examining students' answer sheets to evaluate the quality of the test items, including item validity and reliability, followed by an analysis of the effectiveness questionnaire administered to all students after the instrument was used. In this stage of data analysis, all data were measured using a Likert scale, as presented in Table 2.

Table 2. Likert Scale Scoring Criteria

No	Category	Score
1.	Very Good	4
2.	Good	3
3.	Fair	2
4.	Poor	1

Based on Table 2, each response category is assigned a specific score, ranging from "Very Good" with a score of 4 to "Poor" with a score of 1. These scores are used in the data processing to determine teachers' and students' responses to the developed evaluation instrument. The questionnaire responses are then processed to calculate the instrument's validity. The validity score can be calculated using the following formula:

$$V_s = \frac{\text{Total Score per Indicator}}{\text{Maximum Score per Indicator}} \times 100\%$$

After the percentage results were obtained, the validity level of the developed product was then categorized according to the product validity criteria presented in Table 3.

Table 3. Instrument Validity Percentage Criteria

Level of Validity (%)	Criteria
85,01% – 100,00%	Very Valid
70,01% – 85,00%	Valid
50,01% – 70,00%	Less Valid
01,00% – 50,00%	Invalid

Adapted based on [13]

Based on Table 3, the validity percentage results obtained can be interpreted according to the established criteria. The higher the percentage, the higher the instrument's validity. Instruments categorized as "Very Valid" or "Valid" are considered feasible for use, whereas instruments in lower categories require revision and cannot be used if they

fall into the “Less Valid” or “Invalid” categories. After the validity analysis, the next step is to calculate the practicality score. The practicality score is calculated using a predetermined formula, and the classification results are adjusted according to the criteria in Table 4.

$$Vp = \frac{\text{Average Score}}{\text{Maximum Score}} \times 100\%$$

Table 4. Instrument Practicality Percentage Criteria

Level of Validity (%)	Criteria
85,01% – 100,00%	Very Practical
70,01% – 85,00%	Practical
50,01% – 70,00%	Less Practical
01,00% – 50,00%	Not Practical

Adapted based on [13]

Based on Table 4, the obtained practicality percentage is interpreted according to the established criteria. The instrument is categorized as *Highly Practical* or *Practical* when the percentage falls within the range of 70.01–100%, while percentages below this range indicate that the instrument requires further revision. After assessing practicality, the next step is to evaluate the instrument's effectiveness by analyzing students' responses to determine whether it accurately measures their abilities. The students' answers are further examined to evaluate item validity and reliability. The quality of students' responses is assessed using the scoring rubric for mathematical problem-solving skills, and the results are then classified into the categories presented in Table 5.

Table 5. Categories of Students' Mathematical Problem-Solving Ability

Ability Category	Score
High	$x > 75$
Medium	$55 \leq x \leq 75$
Low	$x < 55$

Adapted from [14]

After obtaining the students' responses, the answers were analyzed through item validity and reliability testing. The effectiveness questionnaire scores were calculated using the predetermined formula, and the classification results were interpreted according to the criteria presented in Table 6.

$$N = \frac{\text{Total Score Obtained}}{\text{Maximum Score}} \times 100\%$$

Table 6. Instrument Effectiveness Percentage Criteria

Level of Validity (%)	Criteria
85,01% – 100,00%	Highly Effective
70,01% – 85,00%	Effective
50,01% – 70,00%	Less Effective
01,00% – 50,00%	Not Effective

Adapted based on [13]

According to the instrument effectiveness levels presented in Table 6, the evaluation instrument product is considered good and feasible for use if it is deemed effective by students and meets the minimum effectiveness percentage for the “Effective” criterion.

3. RESULTS AND DISCUSSION

The development process in this study followed five stages, namely Analysis, Design, Development, Implementation, and Evaluation [11]. The Analysis stage included examining the need for an evaluation instrument, analyzing the curriculum, identifying student characteristics, and reviewing the learning objectives. The Design stage involved conceptualizing the evaluation instrument, preparing the storyboard, and designing the research instrument. The Development stage focused on producing the contextual ethnomathematics-based evaluation instrument, conducting expert validation by material and evaluation specialists, and revising the product based on expert feedback. Individual testing and small-group trials were conducted to assess the instrument's practicality. The Implementation stage consisted of a large-group field test to evaluate the instrument's effectiveness in actual classroom learning. Finally, the Evaluation stage was conducted to determine the overall quality of the developed instrument and to make improvements where necessary. The development of the evaluation instrument comprises the following stages:

3.1. Results

1. Analysis Stage

In the analysis stage, it was identified that the evaluation instruments used by ninth-grade mathematics teachers were not specifically designed to assess students' problem-solving abilities and were not connected to ethnomathematical contexts. Therefore, a more contextual ethnomathematics-based evaluation instrument was needed. Curriculum analysis was then conducted to ensure alignment with the *Merdeka Curriculum* implemented at the school, particularly the learning outcomes related to geometry and measurement in polyhedron topics. The analysis of student characteristics indicated that students demonstrated varying levels of ability, with many still experiencing difficulties in solving word problems. This highlighted the need for instruments that present problems in real-life contexts to enhance comprehension. In addition, learning objective analysis was conducted to ensure that the developed instrument accurately and systematically measures students' problem-solving abilities, consistent with the curriculum goals and insights from teacher interviews.

2. Design Stage

After gathering information from the analysis stage, the next step was to design the evaluation instrument by integrating the content of polyhedra (three-dimensional shapes with flat faces). The evaluation instrument was designed to measure students' ability to solve geometric problems by connecting them to ethnomathematical objects. The developed evaluation instrument consists of test and non-test components. The test

component includes essay-type questions on polyhedron concepts, such as volume and surface area. This stage involved formulating indicators, developing a test blueprint aligned with learning outcomes and subject content, and preparing a scoring rubric based on criteria for ethnomathematics-based mathematical problem-solving tasks. Meanwhile, the non-test instruments include project worksheets, group presentation project assessments, student activity observation sheets during problem-solving, student attitude questionnaires, and scoring guidelines for the attitude questionnaires.

3. Development Stage

The development stage is a continuation of the design phase. In this stage, several activities were carried out, including expert validation of the research instruments and testing the quality of the evaluation instrument. The quality assessment included validity, practicality, and effectiveness testing. These three aspects were used to determine the feasibility of the evaluation instrument as an assessment tool for implementation in the learning process. The steps undertaken in the development stage are as follows:

Validity Analysis

In the validity testing stage, assessments were conducted by material experts and evaluation experts using a questionnaire. The results of these assessments served as the basis for determining whether the instrument was feasible for use or required revisions in certain parts.

a. Material Expert Validation

In the material validation test, the validators, acting as material experts, aimed to provide feedback and assessment on the developed evaluation instrument, conducted by the team of material experts. The aspects of content assessment included content feasibility, language aspect, and construct (component) feasibility. The results of the material validation by the material experts can be seen in Table 7 below:

Table 7. Material Expert Validation Results

Validator	No	Assessment Indicator	Total Score	Maximum Score	Percentage (%)
Material Expert	1.	Content Feasibility	55	64	85,93%
	2.	Language Aspect	19	24	79,16%
	3.	Component Feasibility (Construct)	21	24	87,5%
		Final Result Criteria	104	112	84,82%
				Valid	

Based on the assessment results presented in Table 7, the instrument obtained a total score of 104 out of a maximum score of 112, with a validity percentage of 84.82%. According to the validity criteria, these results indicate that the instrument falls into the “Valid” category, making it feasible for use in the next stage after revisions are made in line with expert suggestions.

b. Evaluation Expert Validation

After the material validation stage by the material experts, the evaluation validation was conducted. In the evaluation validation stage, a questionnaire was used as a measurement tool to assess the instrument from an evaluation perspective. The aspects assessed included instrument construction, measurement quality, assessment techniques, and language feasibility. The validation results are presented in Table 8.

Table 8. Evaluation Expert Validation Results

Validator	Total Score	Maximum Score	Percentage
Validator 1	39	44	88,63 %
Validator 2	36	44	81,81%
Final Result	75	88	85,22 %
	Criteria		Very Valid

Based on the assessment results presented in Table 8, the instrument obtained a total score of 75 out of a maximum score of 88, with a validity percentage of 85.22%. According to the validity criteria, these results indicate that the instrument falls into the “Very Valid” category, making it feasible for use in the next stage after revisions are made in line with expert suggestions.

Practicality Analysis

In the practicality testing stage, assessments were conducted by teachers and students using response questionnaires. The results of these assessments were used to determine whether the evaluation instrument was easy to use, understandable, and suitable for implementation in learning. The findings from the practicality test served as the basis for determining whether the instrument was already practical or still required revisions to be more effectively used in the classroom.

a. Individual Trial

The individual trial was conducted to obtain initial feedback from educators regarding whether the developed evaluation instrument was practical for use before being tested on students. The individual trial involved one ninth-grade mathematics teacher. During this stage, a questionnaire was used to assess practicality, including ease of use, alignment with learning objectives, time efficiency, and completeness of components. The practicality results are presented in Table 9.

Table 9. Teacher Practicality Questionnaire Results

Validator	Total Score	Maximum Score	percentage
Validator	43	44	97,7 %
	Criteria		Very Practical

Based on the assessment results presented in Table 9, the instrument scored 43 out of 44, with a practicality percentage of 97.7%. According to the practicality criteria, these results indicate that the instrument falls into the “Very Practical” category. Therefore, the

instrument can be used in the next stage as it was deemed easy to understand, aligned with learning, and practical for teachers to use.

b. Small-Group Trial

After the individual trial stage, the next step was the small-group trial, which involved nine students with high, medium, and low ability levels. In this stage, a questionnaire was used to assess practicality, including ease of use, alignment with learning, and feasibility. The practicality results are presented in Table 9.

Table 9. Student Practicality Questionnaire Results

Instrument	No	Assessment Indicator	Total Score	Maximum Score	Percentage (%)
Practicality Questionnaire Results	1.	Ease of Use	148	180	82,22%
	2.	Alignment with Learning	116	144	80,5%
	3.	Feasibility	83	108	76,85%
Final Result Criteria			347	432	80,32%
				Practical	

Based on the assessment results presented in Table 9, the instrument obtained a score of 347 out of a maximum of 432, with a practicality percentage of 80.32%. According to the practicality criteria, these results indicate that the instrument falls into the “ Practical” category. Therefore, the instrument can be used for students with high, medium, and low ability levels, as it is considered capable of helping them better understand the material and solve problems.

4. Implementation Stage

The next stage was field implementation, during which 29 students evaluated the instrument's effectiveness in measuring ethnomathematics-based problem-solving abilities. The purpose of this stage was to assess students' problem-solving performance and to examine the validity and reliability of the test items.

a. Students' Test Results Based on Ability Categories

The test results were analyzed to examine the distribution of students' abilities after the instrument was used. The distribution is presented in Table 10.

Table 10. Assessment Results of Students' Mathematical Problem-Solving Ability

Student Category	Number (N)	Average Score
High	1	78,8
Medium	1	55,6
Low	27	28
Overall Average		30,68

Based on the results of the mathematical problem-solving test, the average score obtained was 30.69, which falls into the low category. Of the 29 students, 27 were in the low category, one in the medium category (average score of 55.6), and one in the high

category (average score of 78.8). These results indicate that students' overall problem-solving abilities remain low.

b. Empirical Item Validity Results

Empirical validity was assessed using the Pearson product–moment correlation to examine the relationship between test scores and problem-solving indicators. The results of the validity test are presented in Table 11.

Table 11. Item Validity Test Results

Item No	r Count	r table	Conclusion	Criteria
1	.704**	0.367	Valid	High
2	.703**	0.367	Valid	High
3	.684**	0.367	Valid	Medium
4	.698**	0.367	Valid	Medium
5	.817**	0.367	Valid	High
6	.721**	0.367	Valid	High
7	.641**	0.367	Valid	Medium
8	.621**	0.367	Valid	Medium
9	.621**	0.367	Valid	Medium
10	.621**	0.367	Valid	Medium

Based on the calculations presented in Table 11, all items have r-count values greater than the r-table value (0.367). Therefore, all ten items are declared valid and suitable for assessing students' mathematical problem-solving abilities.

c. Instrument Reliability Results

The instrument's reliability was assessed using Cronbach's Alpha to evaluate internal consistency. The results are presented in Table 12.

Table 12. Test Results of Reliabilities

Reliability Statistics	
Cronbach's Alpha	N of Items
.831	10

Based on Table 12, the Cronbach's Alpha value was 0.831 with 10 items. Therefore, it can be concluded that the developed evaluation instrument has high reliability.

Effectiveness Analysis

In the effectiveness testing stage, assessments were conducted through an effectiveness questionnaire completed by students after using the evaluation instrument. This assessment aimed to determine whether the instrument helped students understand the material, facilitated problem-solving, and enhanced the learning experience. The results

from the effectiveness questionnaire were used to determine whether the instrument had been effectively applied in learning or still required further improvement. The effectiveness test was conducted with all students in class IX B. In this stage, a questionnaire was used to measure effectiveness, assessing aspects such as understanding, problem-solving ability, and the clarity of the instrument. The effectiveness results are presented in Table 13.

Table 13. Student Effectiveness Questionnaire Results

Instrument	No	Assessment Indicator	Total Score	Maximum Score	Percentage (%)
Effectiveness Questionnaire Results	1.	Effectiveness	483	580	83,27%
	2.	Understanding and Problem-Solving Ability	410	464	88,36%
	3.	Instrument Clarity	413	464	89%
Final Result Criteria			1306	1508	86,6%
				Very Effective	

Based on the assessment results presented in Table 10, the instrument obtained a total score of 1306 out of a maximum of 1508, with an effectiveness percentage of 86.6%. According to the effectiveness criteria, these results indicate that the instrument falls into the “Very Effective” category. Therefore, the developed evaluation instrument is considered capable of helping students understand the material and supporting the problem-solving process, making it feasible for use in learning.

5. Evaluation Stage

The evaluation stage in the ADDIE model is carried out continuously throughout each part of the development process to ensure that the procedures implemented and the resulting product truly meet the required standards and user needs. Evaluation is not only conducted at the end of the process but is also applied at every stage, allowing necessary improvements to be made before proceeding to the next phase.

3.2. Discussion

The results of the study indicate that the developed ethnomathematics-based evaluation instrument has met the criteria of validity, practicality, and effectiveness. These findings suggest that the instrument is feasible for measuring students’ problem-solving abilities on the topic of flat-sided three-dimensional shapes.

The results of this analysis consistently demonstrate that the developed ethnomathematics-based evaluation instrument is effective in measuring students’ problem-solving abilities. These findings align with previous research [15] and support the research objective that developing an appropriate and valid evaluation instrument is essential to improving the quality of education. The study indicates that developing an ethnomathematics-based evaluation instrument has a positive impact on mathematics learning. This success can be explained by several key aspects, namely that integrating ethnomathematics into mathematics learning has been proven effective in assessing

students' problem-solving abilities. This aligns with Wulandari et al. [16], who show that ethnomathematics plays an important role in establishing a connection between mathematics and societal realities, particularly in the context of learning previously non-contextual.

Based on the results of the validity analysis conducted by the validators, the developed evaluation instrument was found to be very valid, with average percentages of 84.82% and 85.22% for material expert validation and evaluation expert validation, respectively. This is in accordance with Nurfitriani [17], which states that an evaluation instrument is considered valid if it falls within the 81%–100% range, meaning that the ethnomathematics-based evaluation instrument can be used to measure students' problem-solving abilities.

Based on teacher and student response questionnaires, the percentage for teachers was 97.7%, and the average student response was 80.32%, resulting in an overall practicality percentage of 89%. This indicates that the developed evaluation instrument meets the practicality criteria in the "Very Practical" category, making it suitable for student use. This finding aligns with Wandhi [18], which states that teacher and student responses are considered very practical if the average percentage is above 81%–100%.

Regarding effectiveness, the research results showed a 86.6% effectiveness rate. According to Fatmawati et al. [19], an evaluation instrument is considered effective if completeness exceeds 80%. Consistent with this theory, the obtained percentage indicates that the evaluation instrument meets the effectiveness criteria, falls into the "Very Effective" category, and is effective for use in the learning process.

The ethnomathematics-based evaluation instrument developed in this study provides a significant contribution to mathematics learning, particularly in enhancing students' problem-solving abilities [20]. The use of Jambi cultural context in this instrument helps students build connections between flat-sided three-dimensional shape concepts and the cultural forms they frequently encounter [21]. Through local cultural representation, students can more easily visualize objects and problem situations, allowing the processes of information identification, analysis, and strategy selection to be carried out more efficiently [22]. The cultural context used also fosters an emotional connection, making students more interested and motivated to solve the problems [23].

In terms of problem-solving ability, the developed evaluation instrument was designed based on Polya's thinking indicators, so students are not only required to arrive at the final answer but also to engage in a complete mathematical thinking process [24], [25]. Ethnomathematics serves as an effective means to enrich the context at each stage of problem-solving [8], [26]. This instrument does not merely measure problem-solving ability mechanically but also evaluates how students interpret information within their cultural context [27], [28].

4. CONCLUSION

The findings of this study indicate that the ethnomathematics-based evaluation instrument can be used effectively to measure students' problem-solving abilities. The problem-solving questions developed demonstrated strong potential to affect students' test

performance, as they comprehensively assessed problem-solving skills. Although the instrument developed in this research is valid, practical, and effective, and all items have been confirmed as valid and reliable, several limitations remain. This study was conducted with a limited student sample, which limits the generalizability of the results, and the instrument focused solely on polyhedra, limiting its applicability to other mathematical materials and to different cultural contexts. Future research is recommended to expand the instrument to cover additional mathematical topics and to develop digital or multimedia-supported evaluation tools to create more interactive, accessible, and contextually relevant products.

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