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Development of Central Javanese Ethnomathematics-Based E-Learning Materials to Enhance Students' Learning Interest and High-Order Thinking Skills

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Abstract: This study aims to develop educational materials rooted in Central Javanese culture and based on indigenous mathematics, with a view to stimulating students' interest in learning and fostering their higher-order thinking skills. This study adopts a research and development method based on the Borg and Gall model, modified into eight stages: identification of potential issues, data collection, product design, design validation, design revision, product trialing, product revision, and user trialing. The research utilized a two-group pretest-posttest design comparing a control class and an experimental class. Data analysis techniques included the paired-sample t-test, independent-sample t-test, and N-gain analysis. Several experts conducted product validation. The validation results from the content expert yielded a score of 95.83% (highly acceptable), the media expert scored 93.75% (highly acceptable), and the language expert scored 94.79% (highly acceptable). The practicality test of the teaching materials among students yielded a score of 98.3% in the control group and 99.2% in the experimental group, indicating high practicality. Meanwhile, the practicality test by teachers in the control group and the experimental class each yielded a score of'100%, indicating high practicality. The independent sample t-test showed a statistically significant difference in student's learning interest between the experimental and control groups (sig < 0,05), with N-Gain score of 0,60 for experimental group and 0,38 for control group. Similarly, a statistically significant difference was found in students' higher-order thinking skills between the two groups (sig < 0,05), with n-Gain scores of 0,61 for experimental group and 0,38 for the control group. This study demonstrates that applying ethnomathematics-assisted learning to the multiplication and division of decimal numbers can enhance interest in learning and higher-order thinking skills. This study concludes that the developed teaching materials meet high standards in both effectiveness and practicality, making them a viable option for mathematics instruction at the elementary school level.

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Introduction

Education can take various forms, types, and levels that encourage individuals to develop their potential in order to create an advanced and civilized society (Astuti et al., 2023; Nurjanah & Maulana, 2023). In today's era of globalization, education should teach local cultural values that shape national identity alongside science and technology (Monoarfa et al., 2024). Education that integrates local wisdom is one effective strategy for building cultural identity among the younger generation (Sarumaha et al., 2024). Integrating culture into education can enhance the quality of learning by drawing on local contexts. (Ayu et al., 2024; Lakapu et al., 2025; Walad et al., 2025).

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One of the learning issues frequently encountered is in mathematics education. The most common issue is students' low interest in learning mathematics. This can further influence students' high-level thinking abilities in solving various mathematical problems that require HOTS. Students often think mathematics is an abstract subject and difficult to understand (Ye et al., 2023). Additionally, mathematics is perceived as less relevant to their daily lives (Wisenöcker et al., 2024). The PISA (Programme for International Student Assessment) results support this finding. According to the 2022 PISA survey, Indonesian's mathematics skills remain below the OECD (Organization for Economic Co-operation and Development) average. The data show that only about 18% of Indonesian students reached Level 2 in mathematics, which stands in stark contrast to the 69% average recorded across all OECD member countries (OECD, 2023). One of the topics that students find particularly challenging is multiplying and dividing decimals by whole numbers (He, 2025). A previous study indicates that many students struggle with learning decimals (Aini et al., 2025). This finding is supported by earlier research, which emphasizes that multiplying and dividing decimals are essential concepts to master (Peanark et al., 2023). The study identified several reasons why students struggle with decimals. These include a passive learning environment, teacher-centered instruction, and a lack of interest in learning mathematics.

A similar phenomenon was also observed at SD Negeri Krapyak. Data collected through interviews, observations, and questionnaires revealed problems in fourth-grade mathematics instruction. Some of the challenges include teachers' tendency to rely on direct instruction, lectures, and demonstrations. Learning resources at the school are also limited to the school's textbook. Additionally, teachers rarely incorporate technology into their lessons. Furthermore, the problems faced by students include their perception that mathematics is a very difficult and boring subject. Many of them tend to avoid studying mathematics both at school and at home, feel anxious when encountering mathematics lessons, and believe that mathematics is not useful for real-life situations. Further observation revealed that fourth-grade students still demonstrate limited engagement in learning and underdeveloped higher-order thinking skills, especially in decimal numbers.

These challenges in teaching decimal numbers can be addressed through several strategic efforts, such as the use of information technology and digital teaching that support the learning process (Delita et al., 2022; Pereda et al., 2025). One reason for students' low learning outcomes is the limited availability of teaching materials. Among the many types of teaching materials available, ethnomathematics-based teaching materials are highly effective for enhancing learning (Ula et al., 2024). According to D'Ambrosio (1985), in (Nuryami & Apriosa, 2024), ethnomathematics is mathematics situated within or practiced in a community's culture, spanning from children to adults. The purpose of ethnomathematics is to introduce the public to alternative approaches to teaching mathematics by linking it to the local culture. However, previous ethnomathematics research has tended to focus primarily on using cultural contexts to introduce mathematical concepts and improve learning outcomes; there has been limited development of digital learning materials specifically designed to address the conceptual difficulties associated with decimal numbers. Furthermore, few studies have integrated the cultural context of Central Java with digital activities oriented toward HOTS that encourage students to analyze, evaluate, and solve mathematical problems within a contextual framework.

Ethnomathematics teaching materials are teaching materials designed by teachers to support classroom learning by combining mathematical concepts with cultural backgrounds in certain regions (Bidiyah & Trisniawati, 2024; Kumar & Gopinath, 2025). The practice of integrating ethnic mathematics into classroom teaching is consistent with the aims of the

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current Merdeka curriculum, which emphasizes contextual learning, differentiated instruction, and the incorporation of local cultural wisdom (Bin et al., 2025). Ethnomathematics can be developed and adapted to reflect the cultural heritage of a specific region, such as Central Java's traditions and customs. Cultural elements from Central Java that can be incorporated into mathematics education include traditional clothing, traditional cuisine, and handicrafts. Integrating cultural contexts into mathematics teaching has been shown to significantly enhance learning outcomes in the classroom (Istiningsih et al., 2026; Shahidayanti et al., 2024; Supriyadi et al., 2024). For example, a previous study combined the Pupu culture of Sumatra with teaching content on numerical patterns (Aulia et al., 2025). These findings indicate that students' ability to identify, analyze, and apply numerical patterns in mathematical problems has improved. Furthermore, findings from other studies have indicated that ethnomathematics-based e-modules grounded in local wisdom are effective in boosting learning motivation among elementary school students (Winangun et al., 2024).

Based on these considerations, the researcher is committed to developing learning materials based on Central Javanese ethnomathematics that integrate the concept of decimal numbers with local cultural practices relevant to students' daily lives. These materials will be designed systematically and contextually to bridge the gap in understanding abstract mathematical concepts while fostering students' learning interest and higher-order thinking skills. The novelty of this product lies in the integration of mathematical content and the cultural context of Central Java, presented in a digital format. Furthermore, the activities and problems included go beyond a focus on lower-order thinking skills (LOTS); they systematically encourage higher-order thinking skills (HOTS) through analysis, evaluation, and the resolution of contextual problems. This distinguishes the materials from conventional teaching resources, which tend to be text-heavy and often fail to link mathematical concepts to students' cultural experiences. This research aims to produce digital teaching materials based on Central Javanese ethnomathematics that are valid, practical, and effective in supporting the learning interest and higher-order thinking skills of fourth-grade elementary school students.

Research Method

This study employs a research and development method, utilizing an adapted version of the Borg and Gall development model as its primary framework. The research stages begin with analyzing potential problems, collecting data, designing the product, then validating the product, carrying out design revisions, carrying out product trials, carrying out product revisions, and carrying out usage trials to obtain the final product. The developmental design implemented in this study follows a two-group pretest-posttest structure. The first stage was problem analysis through interviews, observation, and documentation to find problems that existed in the research location. The second stage was data collection, carried out via teacher and student needs surveys. Third, designing products by looking at and considering the needs of teachers and students, which were provided through a needs questionnaire. The fourth stage was design validation by subject matter experts, media experts, and language experts. The next stage was a product pilot test conducted on a small group consisting of 12 fourth-grade students from class 4A at SD Negeri Krapyak. Finally, a usage pilot test was conducted on a large group in the experimental class. In addition, there was also a control class that participated in learning without using the product under development.

Participants of this study were categorized into two groups: product trial subjects and usage trial subjects. The selection of product trial subjects was conducted through purposive

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sampling; the subjects chosen for this small-scale trial were twelve students in class IV A of SD Negeri Krapyak, selected into three categories based on their cognitive abilities. Meanwhile, the research subjects for the usage trial employed cluster random sampling with two categories: a control class and an experimental class. The control class consisted of all 27 students in class 4B, while the experimental class consisted of all 25 students in class 4C at SD Negeri Krapyak.

There are two types of data used in this research. First, quantitative data included the final semester summative assessment (SAS) scores of fourth-grade students in mathematics, pretest scores, posttest scores, and evaluations from expert validators. Second, qualitative data were obtained from interviews, observations, teacher and student needs questionnaires, and documentation. The data sources in this study were the fourth-grade teacher at SD Negeri Krapyak, the fourth-grade students at SD Negeri Krapyak in three classes, content validators, media validators, language validators, and the researcher herself.

Two data collection techniques were used. First, the test technique, which in this study included pretests and posttests administered to students before and after the intervention. Second, the non-test techniques employed included interviews, observations, documentation, and questionnaires. This study employed at least two data analysis techniques. First, the initial data analysis utilized tests for normality and homogeneity. Subsequently, the final data analysis employed the paired-samples t-test, the independent-samples t-test, and the n-gain analysis. To determine whether the developed product affected on mathematics learning, the t-test was used. The paired-samples t-test was conducted at a 5% significance level. Next, an independent t-test was performed to compare the mean post-test scores between the control class and the experimental class. Subsequently, to assess the effectiveness of the developed product, an N-Gain test was conducted using SPSS version 25. After the N-Gain values were obtained, they were categorized into three groups: if the N-Gain value exceeded 0.7, it was classified as high; if it was between 0.3 and 0.7, it was classified as moderate; and if it was below 0.3, it was classified as low (Hake, 1999). Furthermore, the effectiveness of the product was further determined based on four percentage-based N-Gain categories: scores above 76% were considered effective; scores between 56% and 75% were considered moderately effective; scores between 40% and 55% were considered to have a weak effect; and scores below 40% were classified as ineffective.

Results and Discussion

Potential Issues

First phase, the researcher conducted a preliminary study at SD Negeri Krapyak through interviews, observation, and documentation to identify the potential and existing issues in Grade 4 at SD Negeri Krapyak. The researcher identified the following issues: 1) Limited teaching materials used in mathematics instruction; 2) Lack of innovation in the use of teaching materials; 3) Lack of enthusiasm and interest among students during mathematics lessons; 4) Inadequate utilization of technology in instruction; 5) Low final semester summative scores in mathematics; 6) Students have already internalized the mindset that mathematics is difficult; 7) Students have difficulty solving problems that require higher-order thinking.

Data Collection

After identifying potential issues, the researcher proceeded to collect data by distributing teacher needs questionnaires and student needs questionnaires. The findings from these questionnaires will be taken into account when developing online learning materials for ‘ethnic mathematics’. The researcher obtained summary data from the teacher

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and student needs surveys for grades IV A, IV B, and IV C at SD Negeri Krapyak, indicating agreement with the development of ethnomathematics e-learning materials to enhance learning interest and higher-order thinking skills in fourth grade.

Product Design

This product design phase began with creating the layout for the instructional materials to be developed. These ethnomathematics instructional materials were designed for fourth-grade decimal multiplication and division content. The materials were designed in an electronic format accessible via a website. Components to be included in these materials include a collection of materials, instructional videos, practice problems, quizzes, and assessment questions. After the instructional material layout was created, the product development process was carried out using Adobe Illustrator, Adobe InDesign, and the website https://heyzine.com/.

Figure 1. Ethnomathematics teaching materials

Figure 1 illustrates that the ethnomathematics teaching material is designed to integrate digital elements and culture into the study of decimal numbers. The development of this material aligns with the learning outcomes of Phase B of the Merdeka Curriculum. Based on these learning outcomes, the material is designed to foster learning interest and HOTS.

Design Validation

The design validation phase aims to assess the effectiveness of the e-learning materials on indigenous mathematics that have been developed. The validation process involved 6 validators: two subject-matter specialists, two media development experts, and two language professionals. The scores obtained from the content, media, and language validations were then interpreted into five categories: “highly acceptable” (81%–100%), “acceptable” (61%–80%), “sufficiently acceptable” (41%–60%), “less acceptable” (21%–40%), and “unacceptable” (0%–20%). Recapitulation of the validation results of ethnomathematics e-teaching materials by matter, media, and language experts is presented in Table 1.

Table 1. Summary of the validation results for ethnomathematics teaching materials

Experts Validation	Evaluation Aspect	Percentage	
		Validator 1	Validator 2
Subject matter	Alignment with competencies achieved	93,75	100
	Alignment of content and questions	93,75	100
	Presentation	93,75	93,75
Media	Visual design	93,75	93,75
	Ease of use	100	93,75
	Graphics	87,5	93,75
Language	Sentence effectiveness	100	100
	Language rules	93,75	87,5

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Communicative	93,75	93,75
Percentage	**94,4 %**	**95,1%**
Criteria	**Highly acceptable**	**Highly acceptable**

Based on design validation conducted by six validators, all were rated as highly acceptable. Based on these results, the ethnomathematics-based e-learning materials are highly appropriate for elementary school mathematics instruction, particularly for teaching decimal multiplication and division.

Design Revision

After the product design was tested for feasibility by validators, the researcher made design improvements based on suggestions and feedback from subject matter, media, and language experts. Several suggestions and feedback from the validators for improving the ethnomathematics e-learning materials will be presented below.

Table 2. Display of E-Learning Materials Before and After Revision

Validator	Suggestions	Revision
Content	1. Add content explanations for each session. 2. Include answer keys via links or barcodes so they are not immediately visible to students.	1. Add explanations and example problems for each session. 2. Include quiz and assessment answer keys in the form of barcodes.
Media	1. Use more contrasting colors between the background and text. 2. Add a menu to facilitate navigation from one page to another.	1. Change the background color to provide better contrast with the text. 2. Add a menu feature to the instructional material interface.
Language	1. Pay attention to word choice on the discussion results sheet.	1. Change the phrase “Question 1” to “Answer 1” on the discussion results sheet.

Product Testing

Small-group product testing was conducted in Class IV A at SDN Krapyak, with 12 students selected through purposive sampling. Small-group product testing was implemented in Class IV A at SDN Krapyak, with 12 students selected as participants through purposive sampling. During the small-scale trial, the chosen students participated in learning activities that adhered to the instructional procedures outlined in the previously prepared lesson plan.

Following the collection of data from students' learning-interest questionnaires administered before and after the learning activities, along with the pretest and posttest results gathered on a small scale, a normality test was subsequently conducted. The Shapiro-Wilk test for normality in small samples showed significance values of 0.559 and 0.329 for pre-instruction learning interest and higher-order thinking skills, respectively. Meanwhile, the post-instruction significance values were 0.329 and 0.095, respectively. Therefore, it can be concluded that learning interest and higher-order thinking skills within the group follow a normal distribution, thereby satisfying the normality assumption for parametric analysis. Next, a paired-sample t-test will be conducted on the data.

A paired-sample t-test based on the significance level (2-tailed) was conducted on learning interest and higher-order thinking skills (HOTS) before and after instruction, yielding a result of 0.000. If the Sig (two-tailed) value is less than 0.05, it can be concluded that there is a significant difference in learning outcomes before and after using the ethnic mathematics e-learning materials. Next, an N-Gain test will be performed on the learning interest data.

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The N-Gain test in small groups on learning interest indicates a change in the form of an increase in students' learning motivation between before and after instruction on decimal numbers. The increase in students' interest in learning is reflected in an N-Gain score of 0.62, which is considered moderate. By comparison, the N-Gain percentage of 62.07% indicates that these teaching materials fall into the "moderately effective" category. Meanwhile, the N-Gain score of 0.57 suggests that the improvement in students' higher-order thinking skills (HOTS) is moderate, and based on the N-Gain percentage of 57.86%, the materials are classified as 'moderately effective'.

After conducting learning using the ethnomathematics e-learning materials and completing the posttest, teachers and students completed a questionnaire assessing the practicality of the ethnomathematics e-learning materials. This was done to obtain information and feedback on the shortcomings of the teaching materials so that they could be improved upon. In the pilot study of e-learning materials for ethnic mathematics, the aggregated results of the "Student Usability Questionnaire" yielded a total score of 177 points, equivalent to 98.3 percent, indicating a high level of usability. This is in line with the results of the recapitulation of the teacher practicality questionnaire in the small group trial of the ethnomathematics e-teaching materials, which also obtained a very practical category with a score of 15, with a percentage of 100%.

Usage Trial

The usage trial involved two treatment groups: a control class using textbook materials provided by the school and an experimental class receiving the treatment of using ethnomathematics e-learning materials in instruction. Before participating in the lesson, students completed a learning interest questionnaire and took a pretest to measure their cognitive understanding prior to instruction. Afterward, students engaged in learning activities using the ethnomathematics e-learning materials in the experimental class and the school's textbook in the control class. Once the instruction was completed, students took a posttest and filled out a learning interest questionnaire as well as a practicality questionnaire regarding the ethnomathematics e-learning materials developed by the researcher for the experimental class.

After compiling the students' pre-post-instructional learning interest questionnaires, as well as the pretest and posttest results from the control-experimental classes, we first conducted a normality test. The Shapiro-Wilk normality test revealed that, before the teaching intervention, the p-values for learning interest in the control and experimental groups were 0.804 and 0.751, respectively. Meanwhile, the p-values after the intervention were 0.127 and 0.272, respectively. Likewise, the significance values for higher-order thinking skills before instruction in the control-experimental classes were 0.181 and 0.059, respectively, and the post-instruction values were 0.878 and 0.117, respectively. These results indicate that both learning interest and higher-order thinking skills in the control and experimental classes follow a normal distribution. This means that the data meet the normality assumption required for parametric analysis. The data will subsequently be analyzed using a paired sample t-test.

Table 3. Result Paired Sample T-Test

Type Test	Class	Mean	Std. Deviation	Sig (2-tailed)
Learning Interest	Control	27.510	5.69159	0.000
	Eksperimental	46.168	5.39497	0.000
HOTS	Control	28.644	6.81595	0.000
	Eksperimental	45.596	11.23430	0.000

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A paired t-test was conducted to compare the learning interest and higher-order thinking skills of the experimental and control classes. The result, calculated at a two-tailed significance level, was 0.000. This indicates a significant difference in the students' learning interest and higher-order thinking skills before and after the learning activity. These data will subsequently be analyzed using an N-Gain test.

Table 4. N-Gain for Learning Interest in the Control Class

Type Test	N-Gain	N	Min	Max	Mean	Std.Deviation
Learning Interest	N-Gain	27	.24	.50	.3823	.06338
	N-Gain (Percent)	27	23.82	49.97	38.234	6.33804
HOTS	N-Gain	27	.21	.62	.3850	.10583
	N-Gain (Percent)	27	20.75	61.62	38.5012	10.58299

The N-Gain test for learning interest and higher-order thinking skills in the control class showed moderate scores of 0.3823 and 0.3850, respectively, and effectiveness levels of 38.234% and 38.5012%, respectively, which are considered ineffective. The results of the N-Gain test for the experimental class are presented below.

Table 5. N-Gain for Learning Interest in the Experimental Class

Type Test	N-Gain	N	Min	Max	Mean	Std.Deviation
Learning Interest	N-Gain	25	.53	.71	.6038	.04919
	N-Gain (Percent)	25	52.59	70.98	60.379	4.91934
HOTS	N-Gain	25	.37	.89	.6136	.15573
	N-Gain (Percent)	25	36.90	88.80	61.3554	15.57307

The N-Gain test results for learning interest and higher-order thinking skills in the experimental class yielded moderate scores of 0.6038 and 0.6136, respectively, with corresponding effectiveness percentages of 60.379% and 61.3554%, both of which are categorized as fairly effective. Subsequently, posttest data on students' learning interest and higher-order thinking skills from both control-experimental classes were further examined using independent-samples t-tests to compare the two groups.

Table 6. Result of Independent Sample T-Test

Type Test	Sig.	df	Sig (2-tailed)
Learning Interest	.548	50	0.000
HOTS	.216	50	0.000

Using an independent-samples t-test at a significance level (two-tailed), a p-value of 0.000 was obtained, and since 0.000 < 0.05, it can be concluded that there is a significant difference in the average scores for learning interest and higher-order thinking skills between year 4 pupils using ethnic Mathematics e-learning materials and those using the school-provided textbooks.

After conducting the lesson using ethnomathematics e-learning materials and the posttest, teachers and students in the experimental class completed a questionnaire regarding the practicality of using ethnomathematics e-learning materials. The recapitulation of the questionnaire on students' practicality in the experimental class regarding the ethnomathematics e-teaching materials obtained a total score of 372 with a percentage of 99.2%, which is categorized as very practical. Meanwhile, the recapitulation of the questionnaire on teachers' practicality in the experimental class regarding the ethnomathematics e-teaching materials obtained a total score of 15 with a percentage of 100%, which is categorized as very practical.

Discussion

The research results indicate that digital teaching materials incorporating Central Javanese ethnomathematics possess high validity and are effective in enhancing students'

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learning interest and HOTS. These findings are consistent with those of (Indriani et al., 2024), who reported that ethnomathematics based instruments demonstrate high levels of validity, practicality, and effectiveness. However, a key distinction of this study is its integration of Central Javanese cultural contexts, concepts of decimal multiplication and division, and HOTS oriented learning activities within a digital format. Cultural contexts that resonate with students' daily lives can stimulate learning interest and foster higher-order thinking skills through contextual problem solving.

The improvement in HOTS capabilities occurs because Central Javanese ethnomathematics provides authentic contexts that help students bridge real life experiences with mathematical concepts. Abstract decimal concepts can be grasped through concrete cultural situations such as measurement, division, or economic activities involving decimals. Integrating cultural contexts into digital media further reinforces this process through various interactive activities. Consequently, students can progress gradually from concrete experiences to conceptual understanding. This study supports findings indicating that contextual learning can enhance students' learning interest and higher-order thinking skills (Abowei & Ebikiemo, 2023). It also aligns with research by (Asti et al., 2026), which found that integrating cultural elements boosts students' higher-order thinking abilities, as well as findings showing that traditional mathematics-based learning improves students' interest in and conceptual understanding of mathematics (Mosimege & Egara, 2023). Thus, the results of this study do not contradict previous research but rather offer a new contribution to the application of ethnomathematics in enhancing primary school learning.

From both theoretical and practical perspectives, these findings suggest that local culture should not merely serve as a decorative element but should instead be utilized as meaningful educational content that contributes to the development of students' various skills. Expert validation results yielded a score exceeding 90%, indicating that the product is highly acceptable for use. Meanwhile, feedback from validators regarding content additions, navigation, and punctuation served as the basis for refining the product. Revisions are a key component of the product development process; researchers must systematically implement improvements based on their assessment of the product's viability (Frampton et al., 2022). Field trial results indicate that classes using the locally developed mathematics teaching materials demonstrated more significant improvements in both learning interest and higher-order thinking skills. This was accompanied by an increase in student satisfaction from 98.3% to 99.2%. Thus, these findings suggest that integrating Central Javanese culture with digital technology can help students grasp abstract decimal concepts through the concrete experiences provided.

Conclusion

This study developed a set of e-learning materials based on indigenous mathematics, aimed at enhancing year four grade students' enthusiasm for learning and their higher-order thinking skills. The materials were validated by six expert reviewers, who confirmed that they met established standards for content, media, and language quality. Furthermore, positive feedback from both teachers and pupils indicates that these materials are highly practical for classroom use. These e-learning materials integrate indigenous cultural wisdom into the teaching of multiplication and division of decimals. The research findings demonstrate significant differences in learning interest and higher-order thinking skills between the group that used the ethnic mathematics e-learning materials and the group that did not. Students in the class using the materials showed significantly greater progress than those in the class that did not use them.

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Recommendation

In the learning process, teachers can integrate local cultural contexts into mathematics lessons by linking them to cultural objects, activities, or practices familiar to students' lives, thereby making the material more contextual and meaningful. For instance, operations involving the multiplication and division of decimals can be introduced through calculations related to the quantities of materials needed for crafting or the portioning of traditional foods. Furthermore, teachers can guide students to gradually translate these cultural situations into visual representations, tables, or mathematical symbols. In this way, ethnomathematics serves not merely as an illustration but as a bridge enabling students to grasp abstract mathematical concepts.

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