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Developing ETHNOGAME for learning similarity: An ethnomathematics-based approach to enhancing mathematical problem-solving skills

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Abstract

This study aims to develop an ethnomathematics-based educational game application, ETHNOGAME, to enhance eighth-grade students' mathematical problem-solving skills in similarity learning. The research employed the analysis, design, development, implementation, and evaluation (ADDIE) model. The research subjects comprised three expert validators and 53 eighth-grade students at SMP Mandiri Pontianak, Indonesia, selected through purposive sampling. Data were collected using expert validation sheets, teacher and student response questionnaires, and a pre-/post-test based on Pólya's problem-solving framework. The pre-/post-test instrument demonstrated sound psychometric properties, with empirical validity coefficients ranging from 0.88 to 0.94, a moderate difficulty index (0.57-0.67), good discriminating power (0.41-0.42), and a reliability coefficient of 0.73. Expert validation yielded an overall validity score of 85.17% (very valid), comprising 84.67% for media aspects and 85.67% for material aspects. The practicality test produced an overall score of 85.57% (very practical), based on teacher (85%) and student (86.14%) response questionnaires. The effectiveness test revealed a statistically significant improvement from pre-test (mean [M] = 51.21) to post-test (M = 89.25), t (52) = -38.909, $p < .001$, with a very large effect size (Cohen's d = -5.345), suggesting that ETHNOGAME is effective in improving students' mathematical problem-solving competencies. The integration of Pontianak's local Malay cultural heritage — specifically the corak insang pattern and Zapin Melayu music — effectively contextualized abstract geometric concepts within students' familiar everyday experiences. These findings confirm that ETHNOGAME is a valid, practical, and effective instructional medium for improving mathematical problem-solving competencies among eighth-grade students.

Keywords: ethnomathematics, educational game, mathematical problem-solving, ADDIE model, similarity

INTRODUCTION

Mathematical problem-solving is a fundamental competency in mathematics education. Polya (1945) defines problem-solving as the ability to seek solutions to goals that are not immediately attainable, requiring the solver to actively seek the means to achieve them. These skills are classified as higher-order thinking skills (HOTS) and must be systematically developed throughout mathematics instruction (Hodiyanto & Firdaus, 2020; Olivares et al., 2021). Despite their recognized importance, studies consistently report that students experience significant difficulties in solving mathematical problems (Amalina & Vidákovich, 2023; Hodiyanto & Firdaus, 2020; Olivares et al., 2021). These difficulties typically manifest in students' inability to comprehend problem situations, translate verbal descriptions into mathematical models, and

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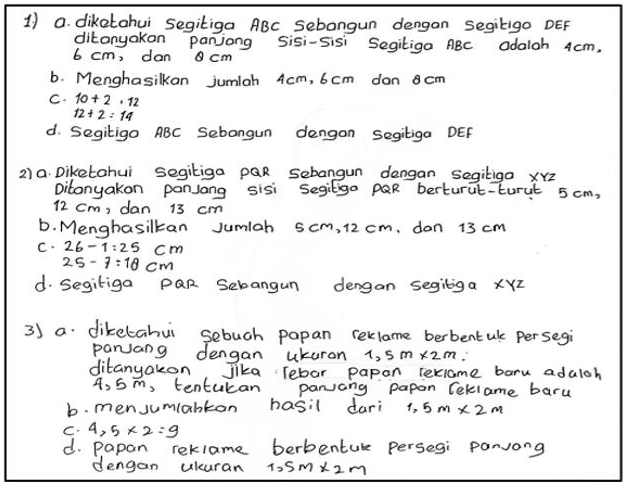
Contribution to the literature

- This study contributes to the growing literature on ethnomathematics-based digital learning by integrating Pontianak's traditional Malay cultural heritage (corak insang pattern and Zapin Melayu music) into a HyperText Markup Language (HTML)-based interactive educational game for junior high school mathematics.
- This research provides empirical evidence for the validity, practicality, and effectiveness of ETHNOGAME, an educational game application developed using the analysis, design, development, implementation, and evaluation (ADDIE) model to support students' mathematical problem-solving skills in similarity learning.
- This study demonstrates that ethnomathematics-based educational games structured around Pólya's problem-solving stages can serve as engaging and culturally responsive instructional media for eighth-grade students, enhancing both mathematical understanding and appreciation of local culture.



1) a. diketahui Segitiga ABC Sebangun dengan Segitiga DEF ditanyakan panjang Sisi-Sisi Segitiga ABC adalah 4cm, 6 cm, dan 8 cm
b. Menghasilkan jumlah 4cm, 6cm dan 8cm
c. 10+2 = 12
12+2 = 14
d. Segitiga ABC Sebangun dengan Segitiga DEF

2) a. Diketahui Segitiga PQR Sebangun dengan Segitiga XYZ Ditanyakan panjang sisi Segitiga PQR berturut-turut 5 cm, 12 cm, dan 13 cm
b. Menghasilkan Jumlah 5 cm, 12 cm, dan 13 cm
c. 26 - 1 = 25 cm
25 - 7 = 18 cm
d. Segitiga PQR Sebangun dengan Segitiga XYZ

3) a. diketahui Sebuah papan reklame berbentuk persegi panjang dengan ukuran 1,5 m x 2 m. ditanyakan Jika lebar papan reklame baru adalah 4,5 m, tentukan panjang papan reklame baru
b. menjumlahkan hasil dari 1,5 m x 2 m
c. 4,5 x 2 = 9
d. Papan reklame berbentuk persegi panjang dengan ukuran 1,5 M x 2 m

1) a. It is known that triangle ABC is similar to triangle DEF, with the side lengths of triangle ABC being 4 cm, 6 cm, and 8 cm.
b. Find the sum of 4 cm, 6 cm, and 8 cm
c. 10 + 2 = 12
12 + 2 = 14
d. Triangle ABC is similar to Triangle DEF
2) a. It is known that triangle PAR is similar to triangle XYZ. The side lengths of triangle PAR are 5 cm, 12 cm, and 13 cm.
b. Find the sum of 5 cm, 12 cm, and 13 cm
c. 26 - 1 = 25 cm
25 - 7 = 18 cm
d. Triangle PAR is similar to Triangle XYZ
3) a. It is known that a billboard is in the shape of a rectangle with dimensions 1.5 m × 2 m. It is given that if the width of the new billboard is 4.5 m, find the length of the new billboard.
b. Calculate the result of 1.5 m × 2 m
c. 4.5 × 2 = 9
d. The billboard is in the shape of a rectangle with dimensions 1.5 m × 2 m

Figure 1. Sample of students' responses to the pre-observation test (created by the authors)

systematically verify their solutions (Amalina & Vidákovich, 2023).

A pre-observation study conducted at SMP Mandiri Pontianak confirmed these challenges. Three word problems related to similarity material were administered to eighth-grade students, and the results revealed critical gaps across all problem-solving stages. While some students could partially identify given information, most were unable to correctly determine what was being asked, construct appropriate solution strategies, or execute and check their work accurately. A subsequent interview with the mathematics teacher on 2 September 2025 further disclosed that the primary contributing factors are students' weak conceptual understanding and the absence of interactive, engaging learning media. These findings are consistent with broader evidence that the availability of engaging, well-designed instructional media is a critical enabler of effective mathematics learning (Engelbrecht & Borba, 2024; Yani et al., 2022). **Figure 1** illustrates a sample of students' responses to the pre-observation test, showing that while students could partially identify given information, they were unable to correctly determine what was being asked, construct appropriate solution strategies, or execute and verify their work accurately.

One promising approach to addressing these challenges is the development of educational games as learning media. Educational games transform the learning process into an enjoyable and challenging experience, thereby motivating students who may otherwise disengage from mathematics (Güler et al., 2022; Poçan et al., 2023). In game-based environments, students are not passive recipients of knowledge but active participants who explore concepts, exercise critical thinking, and engage in problem-solving within meaningful contexts (Engelbrecht & Borba, 2024; Hui & Mahmud, 2023; Li et al., 2024). Malone and Lepper (1987) identify four key characteristics of effective educational games: challenge, curiosity, control, and fantasy — all of which contribute to sustained student engagement and deeper learning. Critically, the choice of a game format — rather than a conventional digital medium such as an e-module or instructional video — is grounded in three pedagogical advantages specific to games. First, games provide immediate, corrective feedback that allows students to reflect on errors iteratively, a process directly aligned with the 'looking back' stage of Polya's framework (Plass et al., 2015; Wouters et al., 2013). Second, the progressive challenge structure inherent in game design sustains cognitive engagement through graduated difficulty, preventing both boredom and

cognitive overload during problem-solving practice (Mayer & Johnson, 2010; Plass et al., 2015). Third, the intrinsic motivation generated by game mechanics — including goal pursuit, reward, and mastery — supports the sustained effort required to develop higher-order mathematical competencies such as problem-solving, which cannot be cultivated through passive exposure alone (Wouters et al., 2013).

Alongside technological innovation, ethnomathematics offers a culturally responsive framework for making abstract mathematical concepts more accessible. Ethnomathematics examines the mathematical practices embedded within specific cultural groups, encompassing the ways in which different communities count, measure, classify, and model patterns in their environment (D'Ambrosio, 1985; Kyeremeh et al., 2023). Integrating ethnomathematics into instruction connects formal mathematical knowledge to students' lived cultural experiences, increasing both motivation and conceptual understanding (Abdulrahim & Orosco, 2020; Firdaus & Hodiyanto, 2019; Hodiyanto et al., 2022; Rosa & Orey, 2016). In the context of Pontianak, the concept of similarity can be naturally explored through the corak insang pattern — a traditional motif of Malay Pontianak culture that embodies geometric principles of proportionality and shape congruence. Such connections not only deepen mathematical comprehension but also foster students' appreciation and preservation of their cultural heritage (Günay & Takunyaci, 2023; Pratama & Afriani, 2025).

A growing body of research has explored the development of ethnomathematics-based educational games and digital learning media for mathematics instruction. Yani et al. (2021) designed Android-based learning media integrating contextual learning to foster problem-solving skills, confirming the positive role of culturally anchored digital tools. Yani et al. (2022) further demonstrated that integrating character education into Android-based m-learning media positively supports students' problem-solving ability. Hodiyanto et al. (2026a) developed ethnomathematics-integrated Android learning media for secondary geometry, reporting significant gains in problem-solving performance, while Hodiyanto et al. (2026b) similarly confirmed that ethnomathematics-embedded Android platforms outperform conventional instruction in problem-solving development. These studies collectively demonstrate that culturally contextualized, technology-mediated learning environments represent a productive and expanding research direction in Indonesian mathematics education.

A critical synthesis of these studies, however, reveals three shared limitations that motivate the present research. First, all reported studies are platform-exclusive — predominantly Android applications requiring device-specific installation — which restricts accessibility for students without compatible devices or in schools with heterogeneous hardware provision (Hodiyanto et al., 2026a, 2026b; Yani et al., 2021, 2022). No existing study has developed a browser-based, installation-free educational game that is universally deployable across device types via a public URL. Second, effectiveness results across studies remain variable, suggesting that pedagogical scaffolding and meaningful cultural anchoring — rather than game mechanics alone — are critical determinants of learning outcomes. Third, while prior studies have incorporated diverse Indonesian cultural traditions, no study has specifically exploited the mathematical properties of the corak insang motif of Malay Pontianak culture as a cultural vehicle for teaching similarity in junior secondary mathematics. This gap represents both a missed opportunity for culturally relevant instruction in West Kalimantan classrooms and an unaddressed area in the ethnomathematics literature (Günay & Takunyaci, 2023; Pratama & Afriani, 2025).

Three deliberate design choices distinguish this study and together constitute its novelty. First, ETHNOGAME is built with HTML and deployed via GitHub pages, enabling students to access the game through any web browser on smartphones, tablets, or laptops without installation — directly addressing the accessibility limitations of Android-exclusive applications identified across existing studies. Second, the content focus on similarity is intentional: similarity is a conceptually demanding topic integrating proportional reasoning, congruence criteria, and geometric modelling, yet it remains underrepresented in the educational game literature relative to topics such as circles, statistics, and arithmetic operations. Third, the corak insang — a traditional diamond-lattice textile motif of Malay Pontianak heritage — was selected as the ethnomathematical anchor because its repeating geometric units instantiate the defining properties of similarity: uniform scaling ratios, preserved angle measures, and proportional side lengths. By embedding similarity concepts within a culturally familiar and aesthetically meaningful context, ETHNOGAME simultaneously targets the cognitive and motivational barriers that characterize student difficulties in this area (Abdulrahim & Orosco, 2020; Firdaus & Hodiyanto, 2019; Hodiyanto et al., 2022).

This study therefore aims to develop ETHNOGAME, an ethnomathematics-based educational game application built with HTML and deployed via GitHub pages, and to evaluate its validity, practicality, and effectiveness for enhancing mathematical problem-solving skills among eighth-grade students on the topic of similarity. The research addresses three specific questions:

(1) To what extent does ETHNOGAME meet the validity criteria for an instructional medium?

(2) How practical is ETHNOGAME as assessed by teachers and students?

(3) How effective is ETHNOGAME in improving students' mathematical problem-solving skills?

MATERIALS AND METHODS

This research employed a research and development methodology using the ADDIE model (Branch, 2009), comprising five sequential stages. The analysis stage involved identifying learning needs, analyzing the curriculum and similarity topic, and examining student characteristics and available technology. The design stage encompassed the development of research instruments, selection of the HTML-based platform with GitHub pages deployment, and construction of the initial structure of ETHNOGAME. The development stage involved building the application, incorporating ethnomathematical elements, and subjecting it to expert validation. The implementation stage comprised a classroom trial using a one-group pre-/post-test design to evaluate the application's effectiveness. The evaluation stage was conducted continuously throughout the process, assessing validity, practicality, and effectiveness, and making iterative refinements based on expert and user feedback (Branch, 2009).

Research Subjects

The research subjects were divided into two groups. The first group comprised three expert validators: two mathematics education lecturers from Universitas PGRI Pontianak, and one information technology and education lecturer from the same university. The second group consisted of 53 eighth-grade students at SMP Mandiri Pontianak, selected through purposive sampling based on the mathematics teacher's recommendation to include students most in need of additional instructional support. Permission to include these eighth-grade students was obtained from the SMP Mandiri Pontianak authorities before data collection commenced. Participants were informed about the purpose of the study, their right to withdraw at any time without penalty, and the measures taken to ensure confidentiality and anonymity. These students participated in a one-group pre-/post-test design to evaluate the effectiveness of ETHNOGAME on mathematical problem-solving skills.

Research Instruments

Three types of instruments were used. First, expert validation sheets assessed the application's validity across media aspects (language quality, effects on learning strategy, software engineering, and visual display) and material aspects (content feasibility, presentation quality, and language appropriateness) using a five-point Likert scale (1 = very poor to 5 = very good). Second, teacher and student response questionnaires measured the application's practicality following the classroom trial, also using a five-point Likert scale. Third, a pre- and post-test, each consisting of four essay items, assessed students' mathematical problem-solving skills based on Polya's four stages: understanding the problem, devising a plan, carrying out the plan, and looking back. The pre-test was administered before the classroom trial to establish students' baseline problem-solving competence on the similarity topic, while the post-test was administered after the trial to measure learning outcomes. Each item carried a maximum score of 10 points, yielding a total maximum score of 40 points per student.

Table 1. Results of empirical validity analysis

Item number	r_{xy}	Criteria
1	0.9037	Very high
2	0.8833	High
3	0.9200	Very high
4	0.9371	Very high

Table 2. Results of IK analysis

Item	Mean score	Maximum score	IK	Criteria
1	5.65	10	0.565	Moderate
2	6.46	10	0.646	Moderate
3	6.65	10	0.665	Moderate
4	5.88	10	0.588	Moderate

Prior to use in the main study, the pre- and post-test instruments underwent a trial administered to 26 students at MTs Al-Irsyad Pontianak on 16 December 2025. Content validity was established through expert review. Empirical validity was computed using the product-moment correlation, with items retained if $r_{xy} \geq 0.70$. The difficulty index (IK) was calculated as the ratio of the mean (M) score to the maximum score, with items accepted if $0.30 < IK \leq 0.70$ (moderate category). Discriminating power (DP) was computed as the difference between upper and lower group means divided by the maximum score, with a minimum threshold of DP > 0.20. Reliability was estimated using Cronbach's alpha (r_{11}), with the instrument considered reliable if $r_{11} > 0.70$ (Hodiyanto et al., 2020). The results of the instrument analysis are presented in tables.

Based on **Table 1**, all four items obtained empirical validity coefficients (r_{xy}) ranging from 0.88 to 0.94, all exceeding the minimum threshold of $r_{xy} \geq 0.70$. This indicates that all items are empirically valid and suitable for measuring students' mathematical problem-solving skills in the similarity topic.

Table 2 shows that the IK of all items ranged from 0.565 to 0.665, all classified as moderate ($0.30 < IK \leq 0.70$). This indicates that the items present an appropriate level of challenge and are neither too easy nor too difficult for the target student group.

As shown in **Table 3**, the DP of all items ranged from 0.408 to 0.423, all exceeding the minimum threshold of

Table 3. Results of DP analysis

Item	Upper group mean	Lower group mean	SMI	DP	Criteria
1	7.69	3.62	10	0.408	Good
2	8.54	4.39	10	0.415	Good
3	8.77	4.54	10	0.423	Good
4	8.00	3.77	10	0.423	Good

Table 4. Reliability analysis results

Coefficient (r_{11})	Criteria
0.727	High

Table 5. Effect size interpretation criteria (Cohen's *d*)

Cohen's *d* value	Category
$d \geq 0.80$	Large effect
$0.50 \leq d < 0.80$	Medium effect
$0.20 \leq d < 0.50$	Small effect
$d < 0.20$	Negligible effect

DP > 0.20. This confirms that the items effectively differentiate between higher- and lower-performing students.

Table 4 presents a Cronbach's alpha coefficient of 0.727, which exceeds the reliability threshold of $r_{11} > 0.70$. This confirms that the instrument is reliable and produces consistent measurements of students' problem-solving competence. Based on the analysis, all four items were retained for use in the main study.

Data Analysis Techniques

Data analysis addressed three criteria. The percentage formula applied for validity and practicality analyses was

$$Percentage\ (\%) = \frac{Total\ obtained\ score}{Maximum\ score} \times 100. \quad (1)$$

The application is classified as valid if the average expert validation score reaches at least 81% (Hodiyanto et al., 2020). Similarly, the application is classified as practical if the average teacher and student response score reaches at least 81%. For effectiveness, a one-group pre-/post-test design was employed. The normality of pre- and post-test score distributions was first examined using the Kolmogorov-Smirnov and Shapiro-Wilk tests (α = .05). When both distributions were confirmed as normal, a paired samples t-test was conducted to determine whether the mean difference (MD) between pre- and post-test scores was statistically significant (α = .05). Effect size was subsequently calculated using Cohen's *d* to quantify the practical magnitude of the learning gain, using the formula *d* = MD/standard deviation (SD) of difference. The interpretation of Cohen's *d* followed the criteria in **Table 5**. All statistical analyses were performed using IBM SPSS statistics version 26.

RESULTS

Analysis Stage

The analysis stage aimed to identify the fundamental needs and problems underlying the development of ETHNOGAME. Two analytical activities were conducted: needs analysis and task analysis.

The needs analysis was conducted through a teacher interview and a student pre-observation test. The interview with the mathematics teacher revealed that students' mathematical problem-solving skills were persistently low, primarily due to limited conceptual understanding and the absence of interactive learning media. The pre-observation test corroborated this finding: students could identify some known information but consistently failed to correctly formulate what was being asked, design solution strategies, or verify their answers. This is consistent with Amalina and Vidákovich (2023), who found that prior domain knowledge, text comprehension skills, and limited exposure to contextual tasks are key factors constraining students' problem-solving performance.

The task analysis identified similarity as the focal material, comprising three sub-topics aligned with phase D curriculum learning objectives:

(1) the definition of similarity,

(2) the conditions for similarity, and

(3) the ratio of sides in similar figures.

These sub-topics were mapped against the prerequisite knowledge students were expected to hold, including proportional reasoning and basic triangle properties.

Design Stage

The design stage involved three primary activities. First, research instruments were developed — including expert validation sheets, teacher and student response questionnaires, and a pre-/post-test — based on Polya's problem-solving indicators. Second, the application platform was selected: HTML was chosen for its cross-device compatibility, enabling access via smartphones or laptops without requiring application installation, while GitHub pages was used for online deployment. Third, the initial product design was constructed under the name ETHNOGAME, structured around three main sections:

- Materials: presenting the concept of similarity through text, images, and examples drawn from the corak insang pattern — a traditional motif of Pontianak's Malay culture — with background music featuring Zapin Melayu to enrich the cultural context.
- Practice Problems: comprising 12 contextual problems explicitly aligned with Polya's four problem-solving stages, guiding students from

Figure 2. Main menu interface of ETHNOGAME (created by the authors)

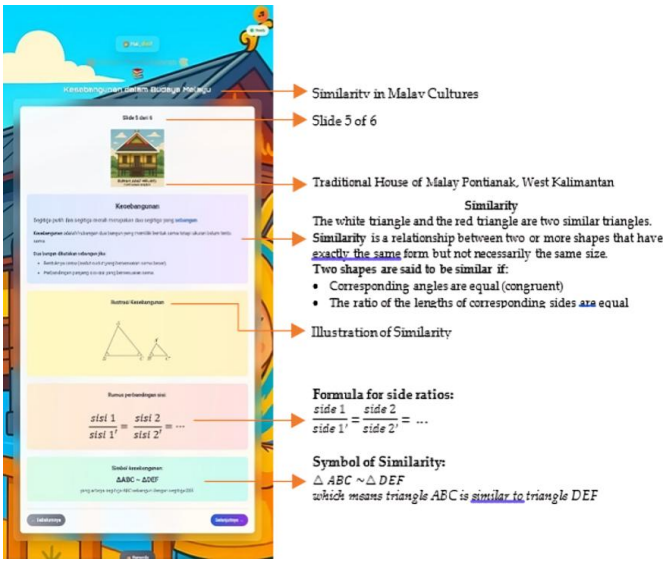


Figure 3. Materials section of ETHNOGAME displaying similarity concepts contextualized through the corak insang pattern (created by the authors)

understanding the problem through to verifying their solution.

- Game: an interactive memory-matching game titled 'Memori Rebana Sebangun,' in which students match geometric representations with their corresponding cultural artefacts from Pontianak's Malay tradition.

The application interface features visual ornaments inspired by the corak insang motif and incorporates Zapin Melayu instrumental music, creating a coherent and immersive cultural environment throughout the learning experience.

Figure 2 displays the main menu interface of ETHNOGAME, featuring three primary navigation

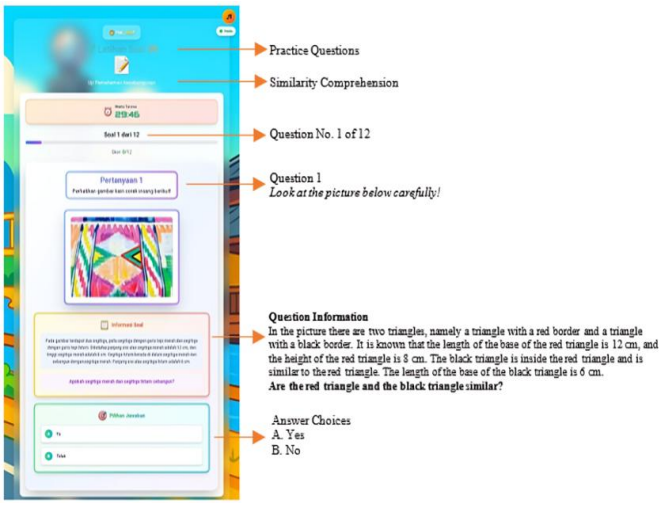


Figure 4. Practice problems section of ETHNOGAME structured around Polya's four problem-solving stages (created by the authors)

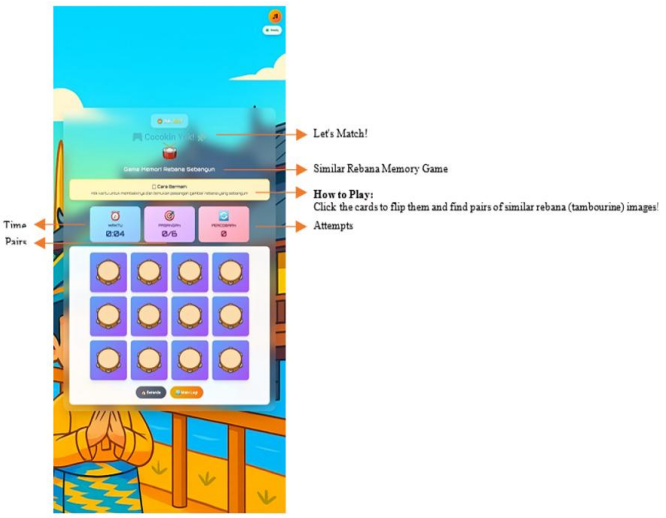


Figure 5. Game section—Interactive memory-matching game featuring Malay cultural artefacts from pontianak (created by the authors)

sections styled with visual ornaments inspired by the corak insang motif.

Figure 3 shows the Materials section of ETHNOGAME, in which similarity concepts are presented through text, images, and culturally contextualized examples drawn from the corak insang pattern, accompanied by Zapin Melayu background music.

Figure 4 presents the Practice Problems section, comprising 12 contextual problems structured around Polya's four problem-solving stages and anchored in the ethnomathematical context of Pontianak's Malay culture.

Figure 5 illustrates the Game section, an interactive memory-matching game in which students match geometric representations with their corresponding Malay cultural artefacts from Pontianak.

Table 6. Results of validation

No	Validator	Percentage (%)		Category
		Media expert	Material expert	
1	Validator 1	85.00	84.00	Very valid
2	Validator 2	84.00	86.00	Very valid
3	Validator 3	85.00	87.00	Very valid
	Average	84.67	85.67	Very valid

Table 7. Summary of overall validation results

No	Validator type	Average (%)	Category
1	Media experts	84.67	Very valid
2	Material experts	85.67	Very valid
	Overall average	85.17	Very valid

Development Stage

The development stage aimed to produce and validate the ETHNOGAME application. Expert validation was conducted by three validators. Media validation was assessed by the validators, covering aspects of language quality, effects on learning strategy, software engineering, and visual display. Material validation was assessed by the validators, covering content feasibility, presentation quality, and language appropriateness. The results are presented in tables. **Table 6** shows the results of validation.

As shown in **Table 7**, the overall average validation score was 85.17%, which exceeds the minimum validity threshold of 81% and is categorized as very valid. This result confirms that ETHNOGAME meets the criteria for content accuracy, communicative language, and visually appropriate design. Media validators noted that the application featured good language quality, a positive impact on learning strategy, appropriate software engineering, and an attractive visual display. Material validators confirmed that the content aligns well with the curriculum learning objectives, presents accurate information with clear and appropriate language, and effectively incorporates ethnomathematical context. Following validation, the primary revision implemented was the addition of a hosting feature to enable teachers to access, monitor, and review students' work through the application.

Implementation Stage

The implementation stage involved a classroom trial in which ETHNOGAME was implemented to 53 eighth-grade students at a secondary school, selected through purposive sampling. Prior to the learning sessions, all 53 students completed a pre-test to assess their baseline problem-solving competence on the similarity topic. The mathematics teacher then integrated ETHNOGAME into the classroom learning process across two learning sessions, during which students demonstrated high levels of enthusiasm and active engagement — exploring the materials, completing practice problems, and playing the memory-matching game. Following the learning sessions, a post-test was administered to all 53 students, and response questionnaires were distributed to both the teacher and students to assess the application's practicality.

Table 8. Results of the practicality test

Respondent	Percentage (%)	Category
Teacher	85.00	Very practical
Students	86.14	Very practical
Overall average	85.57	Very practical

Practicality

The practicality of ETHNOGAME was assessed based on teacher and student response questionnaires completed after the trial. The results are presented in **Table 8**.

The overall practicality score of 85.57% exceeds the minimum practicality threshold of 81%, indicating that ETHNOGAME is very practical. The teacher reported that the application effectively supports learning activities, presents abstract similarity concepts in concrete and culturally contextualized forms, and is easy to operate in classroom settings. Students indicated that the application's attractive design, clear cultural examples, concise explanations, and interactive game elements made learning more engaging and accessible.

Effectiveness

The effectiveness of ETHNOGAME was evaluated using a one-group pre-/post-test design with 53 eighth-grade students. Prior to implementation, students completed a pre-test to establish baseline problem-solving competence. Following the learning sessions using ETHNOGAME, students completed a post-test using equivalent problems. Normality of score distributions was first examined; the results are presented in **Table 9**.

As shown in **Table 9**, both the pre-test (Kolmogorov-Smirnov: $p = .060$; Shapiro-Wilk: $p = .453$) and post-test (Kolmogorov-Smirnov: $p = .054$; Shapiro-Wilk: $p = .178$) score distributions satisfied the normality assumption ($p > .05$), confirming that a paired samples t-test was

Table 9. Results of normality test

	Kolmogorov-Smirnov statistics	df	Kolmogorov-Smirnov significance	Shapiro-Wilk statistics	df	Shapiro-Wilk significance
Pre-test	.119	53	.060	.979	53	.453
Post-test	.120	53	.054	.969	53	.178

Table 10. Descriptive statistics of pre- and post-test scores

	N	Mean	Standard deviation	Standard error mean
Pre-test	53	51.21	10.520	1.445
Post-test	53	89.25	5.076	0.697

Table 11. Results of paired samples t-test

	MD	SD	t	df	p (two-sided)	95% CI lower	95% CI upper
Pre-/post-test	-38.038	7.117	-38.909	52	< .001	-39.999	-36.076

Table 12. Effect size of paired samples

	Standardizer	Point estimate	CI lower	CI upper	Interpretation
Cohen's *d*	7.117	-5.345	-6.401	-4.283	Large effect
Hedges' *g*	7.222	-5.267	-6.308	-4.221	Large effect

appropriate. Descriptive statistics for pre- and post-test scores are presented in **Table 10**.

Table 10 shows that the mean pre-test score was 51.21 (SD = 10.52), reflecting limited prior competence in similarity problem-solving among the 53 students before using ETHNOGAME. The mean post-test score increased substantially to 89.25 (SD = 5.08), indicating a mean improvement of 38.04 points. **Table 11** presents the results of the paired samples t-test.

The paired samples t-test revealed a statistically significant difference between pre- and post-test scores, t (52) = -38.909, p < .001, 95% confidence interval [CI] [-39.999, -36.076]. This confirms that the use of ETHNOGAME produced a significant improvement in students' mathematical problem-solving skills on the similarity topic. **Table 12** presents the effect size.

As shown in **Table 12**, Cohen's *d* = -5.345 (95% CI [-6.401, -4.283]) and Hedges' g = -5.267 (95% CI [-6.308, -4.221]), both of which far exceed the large effect threshold (d ≥ 0.80) established by Cohen (1988). These values indicate that the learning improvement attributable to ETHNOGAME was not only statistically significant but also of very large practical magnitude, demonstrating that the application is highly effective in enhancing eighth-grade students' mathematical problem-solving skills in similarity learning.

Although the calculated Cohen's *d* (-5.345) indicates a very large pre-post change, this value should be interpreted with caution. The magnitude is considerably larger than effect sizes commonly reported in gamified learning research and may be influenced by the low baseline performance, and the and the lack of a control group. Consequently, the effect size should be viewed as reflecting substantial improvement within this specific sample rather than as a directly comparable estimate of intervention effectiveness relative to controlled studies reported in the literature.

Evaluation Stage

The evaluation stage was conducted continuously throughout the development process, with a final review following the implementation trial. Based on the accumulated findings, ETHNOGAME demonstrated strong performance across all three quality criteria: validity (85.17%, exceeding the 81% threshold), practicality (85.57%, exceeding the 81% threshold), and effectiveness — evidenced by a statistically significant pre- to post-test improvement, t (52) = -38.909, p < .001, with a very large effect size (Cohen's *d* = -5.345). The evaluation also identified several areas for future improvement. The application currently requires a stable Internet connection, which limits its use in settings with poor network access. The game component consists of a single memory-matching format, and the application's features — including problem variety and feedback mechanisms — require further development to maximize its educational potential.

DISCUSSION

The results of this study confirm that ETHNOGAME is a valid, practical, and effective instructional medium for enhancing mathematical problem-solving skills in learning similarity. The overall validity score of 85.17% reflects that the application's content, language, and design are well-aligned with the curriculum objectives and the characteristics of eighth-grade students. This finding is consistent with broader research demonstrating that well-validated digital learning media contribute significantly to the quality of mathematics instruction (Arztmann et al., 2023; Barz et al., 2024; Cai et al., 2022; Engelbrecht & Borba, 2024; Hodiyanto et al., 2026a, 2026b). High validity scores reflect the alignment between the application's content design and established pedagogical principles — a necessary precondition for meaningful learning gains in game-based mathematics instruction (Hui & Mahmud, 2023; Yao, 2026).

The very practical classification (85.57%) indicates that ETHNOGAME is easy to use, engaging, and supportive of classroom learning activities. Teachers found the application efficient for transforming abstract geometric concepts into concrete, culturally familiar forms, while students reported higher motivation and interest in mathematics during the trial. This aligns with

Li et al. (2024), who demonstrated that digital educational games significantly enhance student motivation for learning through the mediating role of engagement. The accessibility of ETHNOGAME via smartphones or laptops — without the need for installation — further supports its practical adoption in diverse school settings. This is also consistent with Yani et al. (2021) and Hodiyanto et al. (2026b), who demonstrated that technology-integrated, ethnomathematics-based learning media are accessible, engaging, and effective in supporting students' problem-solving development.

The application's effectiveness was confirmed by a statistically significant improvement from pre-test (M = 51.21, SD = 10.52) to post-test (M = 89.25, SD = 5.08) among 53 students, t (52) = -38.909, p < .001, with a very large effect size, Cohen's d = -5.345, 95% CI [-6.401, -4.283]. The magnitude of this effect warrants critical examination. A second-order meta-analysis by Yao (2026), synthesizing 20 meta-analyses encompassing 688 primary studies published in the British Educational Research Journal, reported a pooled effect size of approximately d = 0.6-0.8 for gamified mathematics learning — substantially lower than the effect size observed in the present study. Similarly, Zeng et al. (2024), in a comprehensive meta-analysis of gamification studies from 2008 to 2023, found a significant but moderate overall effect on academic achievement. Anggoro et al. (2025) specifically reported moderate effect sizes for game-based learning on mathematics HOTS. While Gyedu et al. (2026) observed a large overall effect (Cohen's d = 1.12) for gamification in higher education, the effect size in the present study far exceeds these benchmarks, necessitating careful interpretation.

Several factors may explain the exceptionally large effect size. First, the very low mean pre-test score (M = 51.21 out of 100) indicates that students entered the intervention with severely limited prior competence in similarity problem-solving, creating substantial room for improvement — a condition known to amplify effect size estimates in pre-post designs (Pratama & Afriani, 2025). Second, the absence of a control group means that threats to internal validity — including history effects, maturation, testing effects, and novelty bias — cannot be fully ruled out (Bierer & Colbert, 2024). The novelty effect associated with new educational technology is well-documented as a source of inflated short-term gains in game-based learning research (Feng et al., 2024; Zeng et al., 2024). Third, the relatively short intervention period may have concentrated learning gains into a narrow window, further amplifying the observed pre- to post-test difference. These considerations do not negate the finding's significance but underscore the importance of interpreting d = 5.345 with methodological caution rather than as an unqualified measure of ETHNOGAME's instructional superiority.

Notwithstanding these caveats, three substantive factors provide a theoretically grounded explanation for the strong effectiveness observed. First, the ethnomathematical integration of the corak insang motif provided students with a culturally familiar context for exploring similarity, facilitating meaningful connection between abstract formulas and concrete cultural experiences (Abdulrahim & Orosco, 2020; Günay & Takunyaci, 2023). As Firdaus and Hodiyanto (2019) observe, grounding mathematical concepts in local cultural contexts increases both student motivation and conceptual accessibility. A recent meta-analysis by Pratama and Afriani (2025) confirmed that ethnomathematics-based learning has a significant positive effect on students' mathematical problem-solving skills, while Günay and Takunyaci (2023) demonstrated that ethnomathematics-integrated instruction improves problem-solving performance in geometry. Second, the practice problems in ETHNOGAME were explicitly structured around Polya's four stages, scaffolding students' reasoning from initial comprehension through solution verification. Feng et al. (2024), in a systematic review of gamification's impact on problem-solving, confirmed that game-based interventions with structured problem-solving frameworks consistently produce stronger gains than unguided approaches. A three-level meta-analysis by Cai et al. (2025) further corroborated these findings, reporting a significant positive effect of digital game-based learning on students' problem-solving ability and identifying scaffolded problem-solving tasks as key moderators of effectiveness. Third, the interactive game element promoted sustained engagement and repeated exposure to similarity concepts — conditions known to deepen conceptual understanding and sustain intrinsic motivation (Anggoro et al., 2025; Hui & Mahmud, 2023; Kurnaz & Koçtürk, 2025). More specifically, the memory-matching game 'Memori Rebana Sebangun' required students to repeatedly identify correspondences between geometric representations and their Malay cultural counterparts, reinforcing the defining properties of similarity — proportional side lengths and congruent angles — through repeated, low-stakes retrieval practice. This mechanism is consistent with Wouters et al. (2013), whose meta-analysis of serious games demonstrated that games are particularly effective when they incorporate repeated practice with corrective feedback. The immediate visual feedback within the memory-matching format also allowed students to self-correct their understanding of shape correspondence without teacher intervention, fostering autonomous problem-solving behavior. Furthermore, the progressive score accumulation and challenge structure of the game sustained motivation across the learning session, aligning with Plass et al. (2015), who established that game-based learning enhances affective engagement by providing clear goals, feedback loops,

and a sense of mastery — all of which are prerequisites for deep mathematical learning. Collectively, these mechanisms explain why the game format, rather than a static digital medium, generated the high levels of engagement and learning gains observed in the present study.

The effect size obtained in the present study substantially exceeds outcomes reported in comparable Indonesian studies. Yani et al. (2021, 2022) reported meaningful but more modest learning gains in problem-solving performance for Android-based culturally integrated media. The results also corroborate findings from Hodiyanto et al. (2026a, 2026b), who demonstrated that culturally contextualized, technology-mediated learning environments produce meaningful gains in problem-solving performance among secondary school students. At the global level, the consistency of ETHNOGAME's findings with the positive direction reported across recent meta-analyses (Anggoro et al., 2025; Yao, 2026; Zeng et al., 2024) strengthens confidence in the general effectiveness of game-based ethnomathematics approaches, even where the precise magnitude of effect may be moderated by design conditions.

Nevertheless, these findings must be interpreted with appropriate caution. The one-group pre-/post-test design without a control group limits causal attribution and leaves open the possibility of confounding factors such as history effects, maturation, testing effects, and novelty bias (Bierer & Colbert, 2024). The sample of 53 students from a single school, while more substantial than many prior studies, limits generalizability across different school contexts, regions, and cultural backgrounds. Furthermore, the exceptionally large Cohen's d value should be interpreted as an indicator of the combined potential of ethnomathematics-based game learning under favorable initial conditions — particularly given the very low baseline competence — rather than as a definitive causal claim. Future research should employ quasi-experimental or randomized designs with control groups, include larger and more diverse samples across multiple schools, ensure post-test items are sufficiently distinct from the application's practice content, and conduct longitudinal studies to evaluate whether gains are sustained over time (Feng et al., 2024; Yao, 2026).

CONCLUSION

This study successfully developed ETHNOGAME, an ethnomathematics-based educational game application for eighth-grade similarity learning. Developed through the ADDIE model, the application integrates Pontianak's traditional Malay cultural heritage — specifically the corak insang pattern and Zapin Melayu music — to contextualize abstract geometric concepts within students' everyday cultural experiences. The application achieved an overall validity score of 85.17% (very valid) and a practicality score of 85.57% (very practical), both exceeding the minimum threshold of 81%. In terms of effectiveness, the application produced a statistically significant improvement from pre- to post-test with a very large effect size, suggesting that ETHNOGAME is effective in improving students' mathematical problem-solving skills in similarity learning.

These findings have practical implications for mathematics educators and curriculum developers. Teachers may adopt ETHNOGAME as a culturally responsive and interactive resource for geometry instruction on similarity. The study also provides evidence that ethnomathematics-based educational games structured around Polya's problem-solving framework can effectively cultivate students' HOTS while simultaneously strengthening their appreciation of local culture. It is worth noting that the observed effect size (Cohen's d = -5.345) represents a significant statistical outlier when contrasted with established educational technology meta-analyses. Because the study lacked a control group to isolate natural maturation or instructional confounding variables, this Cohen's d value should be treated strictly as a descriptive internal metric of sample progress rather than a scalable benchmark for ETHNOGAME learning success. Also, the one-group pre-/post-test design limits causal claims due to potential novelty bias or maturation.

Future research should address the limitations of the present study by:

(1) developing an offline-capable version of the application to overcome Internet connectivity constraints;

(2) expanding game features and problem variety to maximize the application's instructional potential;

(3) employing larger, more diverse samples with quasi-experimental or randomized designs with control groups to establish more robust causal evidence; and

(4) constructing post-test items that are clearly distinct from the application's practice examples to ensure more objective measurement of problem-solving outcomes.

Longitudinal studies are also encouraged to evaluate the sustained impact of ETHNOGAME on students' mathematical problem-solving competencies over time.

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