

Integrating Ethnomathematics into Mobile Learning: The Effect of Senimatika on Junior High School Students' Problem-Solving Abilities

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Abstract: This study aims to develop and describe the characteristics, feasibility, practicality, and effectiveness of Senimatika, an Android-based mathematics learning media integrated with an ethnomathematics approach to support junior high school students' mathematical problem-solving skills, particularly in understanding the problem, devising a solution plan, carrying out the plan, and reviewing or verifying the solution. The development of Senimatika was driven by the need for contextual learning media that connect mathematical concepts with students' cultural backgrounds. The research employed the ADDIE development model, consisting of the Analyze, Design, Develop, Implement, and Evaluate stages. The final product, *Senimatika*, presents ethnomathematics-based content through interactive features, contextual problem-solving tasks, and culturally relevant visual designs. Data were collected using expert validation questionnaires, student response questionnaires, pretest, and post-test instruments. The validity analysis using Aiken's V indicated that Senimatika is valid for instructional use, with material experts' ratings classified as "High Validity" ($V = 0.89 - 0.90$) and media experts' ratings classified as "Moderate Validity" ($V = 0.77 - 0.78$). These results demonstrate that the product is valid and feasible for use in mathematics learning. Furthermore, student response data revealed a score of 85.86, categorized as "Very Good", indicating that Senimatika is practical, enjoyable, and easy to use. In terms of effectiveness, the Wilcoxon signed-rank test showed a statistically significant improvement in students' mathematical problem-solving abilities ($V = 22, P < 0.05$). The effect size analysis yielded a moderate effect ($d = 0.557$), confirming the positive impact of Senimatika on students' learning outcomes. Overall, this study concludes that Senimatika is an innovative, effective, and culturally responsive learning media that enhances students' engagement and mathematical problem-solving skills by integrating local cultural elements into digital learning environments.

Keywords: learning media, android, ethnomathematics, geometric transformation, mathematical problem-solving.

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■ INTRODUCTION

Mathematics education today has undergone significant development in line with the times, characterized by an evolutionary, cumulative, and continuous nature. Historically, mathematics learning was conducted in conventional ways, with limited emphasis on collaboration across models, methods, or

approaches. In fact, such integration supports the creation of more contextual learning experiences in the classroom. In mathematics instruction, students should not only be taught to memorize formulas and problem-solving techniques but also be guided to understand how mathematical concepts are applied in real-world situations. The absence of real-life relevance has long been a

major challenge in mathematics education. Many students perceive mathematics as tedious because they struggle to see the connection between mathematical content and everyday life (Sachdeva & Eggen, 2021).

To bridge this gap, teachers can adopt a cultural approach to contextualize mathematics learning (Horn & Garner, 2022). One emerging approach with potential for application in mathematics instruction is ethnomathematics. Through the ethnomathematics approach, teachers and students can utilize cultural ideas, concepts, and activities as learning objects within mathematics instruction. Moreover, culture-based learning aims not only to integrate local wisdom but also to recognize, preserve, and study cultural artifacts and practices (Gadaza et al., 2025; Posti-Ahokas & Janhonen-Abuquah, 2024; Shutaleva, 2023). The ethnomathematics approach has been shown to foster a more authentic learning environment, thereby enabling students to gain a deeper understanding of the practical applications of mathematics (Herawaty et al., 2019; Mania & Alam, 2021; Yanti, 2025). This creates a contextual and meaningful learning experience for students. Ethnomathematics serves as one of the contextual approaches to mathematics learning (Indiyarti et al., 2025; Pathuddin & Nawawi, 2021; Simbolon, 2024). It integrates cultural elements with mathematical concepts found within those cultural contexts (Kabuye, 2024; Machaba & Dhlamini, 2021; Munthahana & Budiarto, 2020). Through this approach, students can explore mathematical ideas such as number systems, geometry, algebra and arithmetic, statistics and probability, measurement, patterns and functions, logic, and problem-solving. Although not every branch of mathematics can be directly identified in a given cultural practice, there are always mathematical elements embedded within cultural expressions (Garcia-Olp et al., 2022; Hilbert, 2022). A range of cultural domains, including but not limited to art,

architecture, number systems, traditional games, and natural patterns, can be analyzed through an ethnomathematical lens. By applying this approach, mathematics learning is expected to help students gain a better understanding of mathematics, deepen their appreciation of their own culture, and enable teachers to more effectively instill cultural values in the classroom.

In addition to being contextual, mathematics learning in the classroom should also be interactive and adaptive, meaning that both teachers and students actively collaborate rather than allowing the teacher to be the sole source of knowledge. One practical implementation is the design of learning activities supported by instructional media (An, 2021; Romiszowski, 2024; Ruiz-Rojas et al., 2023; Smaldino et al., 2019). In the present era, learning media are no longer limited to tangible, physical forms such as pictures, boards, geometric models, or simple counting tools (Fokides & Alatzas, 2023). Instead, they have evolved into digital platforms, particularly Android-based software applications. Advancements in technology have led to numerous innovations in the educational process, making teaching and learning more flexible and less constrained by space and time. Android, in particular, represents a user-friendly, economical, and practical software engineering platform (Abdinejad et al., 2021). Therefore, Android-based learning media are expected to foster greater student independence, promote systematic learning habits, and enhance students' mathematical problem-solving abilities.

The development of Android-based learning media has been widely undertaken in educational training centers such as Balai Besar Guru Penggerak (Teacher Empowerment Center – BBGP) located in several cities across Indonesia, as well as in educational laboratories within many universities with faculties of education and various research centers, both monodisciplinary and multidisciplinary. The

primary goal of developing such learning media is to facilitate the delivery of instructional content in a more engaging manner, foster active learning environments, and support interdisciplinary collaboration and the advancement of science and technology, in alignment with the characteristics of the current *Merdeka Curriculum*. In practice, the development of this learning media is often undertaken by innovative mathematics teachers as part of technology integration to enhance classroom instruction (Shahhida et al., 2020; Zakaria et al., 2023). Furthermore, Android-based learning media are expected to increase students' interest in learning, promote the digitalization of learning materials, and improve students' problem-solving abilities through the structured procedures presented within the media.

Despite the growing use of Android-based ethnomathematics learning media in mathematics education, several pedagogical challenges remain insufficiently addressed. This finding aligns with previous studies on digital ethnomathematics-based learning media, which emphasize that integrating cultural elements, while enriching, requires adequate pedagogical scaffolding to prevent excessive cognitive load (Lestari et al., 2023). Without structured guidance, students may focus more on visual and cultural features than on the underlying mathematical reasoning. Therefore, the present study highlights that the effectiveness of culture-based digital learning media is not inherent to the technology itself but depends on its instructional design and classroom implementation.

Previous studies on Android-based mathematics learning media integrated with ethnomathematics have demonstrated the potential to enhance students' engagement, motivation, and learning outcomes. However, most of these studies emphasize product development, feasibility, and usability, whereas the pedagogical mechanisms by which culturally based digital media support specific mathematical

abilities remain underexplored. In particular, ethnomathematics is often treated merely as a cultural context or visual illustration, rather than as a systematically integrated component of structured problem-solving processes. Moreover, empirical evidence on how Android-based ethnomathematics media support each stage of mathematical problem solving, from understanding the problem to reviewing the solution, remains limited (Lestari et al., 2022). Therefore, there is a clear need for research that not only develops culturally responsive digital learning media but also critically examines its effectiveness in fostering students' mathematical problem-solving skills through a well-defined pedagogical framework.

Existing studies on digital learning media integrated with ethnomathematics have highlighted several strengths, particularly in enhancing students' motivation, cultural awareness, and contextual understanding of mathematical concepts. Digital platforms enable interactive visualization and flexible access, allowing students to explore mathematical ideas embedded in cultural artifacts (Suendarti et al., 2022; Richardo et al., 2023). Nevertheless, several limitations have been reported. Some studies indicate that cultural visual elements may increase students' cognitive load when instructional scaffolding is insufficient, especially for learners with limited digital literacy. Additionally, the implementation of culture-based digital media is often highly dependent on teacher facilitation, and its effectiveness may decline when pedagogical guidance is minimal. These findings suggest that while ethnomathematics-based digital media offer promising opportunities, their instructional effectiveness is strongly influenced by design quality, scaffolding strategies, and alignment with structured learning objectives.

This study was conducted in a junior high school mathematics class, focusing on geometric transformations using an ethnomathematical

approach. The Geometric Transformation topic is included in the second-semester curriculum, in accordance with the research roadmap. Although this topic is not inherently difficult, many students still struggle to identify mathematical elements embedded in cultural contexts. Specifically, the ethnomathematical approach employed in this study incorporates various types of traditional batik patterns. By using these objects, students are expected to analyze patterns and identify mathematical applications within them, with particular focus on those related to geometric transformations. Based on this background, this study aims to address the following questions: 1) What are the characteristics of the developed Senimatika in supporting students' mathematics problem-solving skills? 2) What is the quality of the developed Senimatika in terms of validity, practicality, and effectiveness in supporting students' mathematics problem-solving skills?

METHOD

Participants

This study was conducted at a junior high school in Bandung, West Java Province, Indonesia. The school was selected using purposive sampling based on specific criteria relevant to the study's objectives. The selected school has a distinctive characteristic: it consistently incorporates Sundanese cultural values into various learning activities, making it an information-rich, contextually relevant case selected through purposive sampling. Although

the school does not explicitly implement culture-based learning in its daily instruction, the school emphasizes cultural values more prominently than most other schools, making it an appropriate research setting.

The research participants comprised 17 students, two of whom had special needs. These two students experienced difficulties in participating in learning activities that utilized Android-based learning media. Based on their academic records, both students had repeated grades several times during elementary and junior high school and were therefore categorized as slow learners. However, the learning media used in this study had not been designed or validated to accommodate the needs of students with special needs. Therefore, to ensure alignment between the trial participants and the intended target users of the developed media, these two students were excluded from the study. Consequently, the final sample comprised 15 students.

Research Design and Procedures

This study is a research and development (R&D) project in which an Android-based learning medium was developed using the ADDIE model, comprising the stages: Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model was chosen because it provides a structured approach and can be applied to a range of development products, from test instruments to digital learning media.

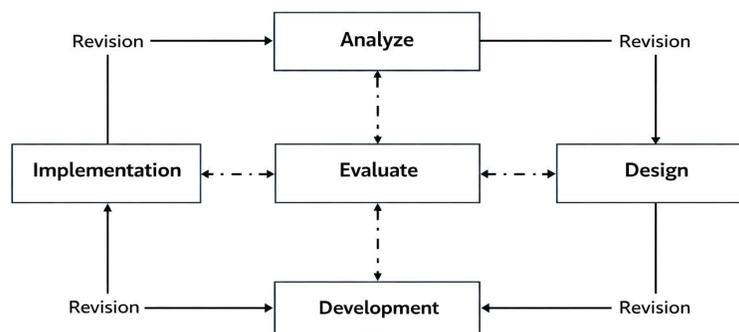


Figure 1. ADDIE Model Diagram

The product development process begins with the Analysis stage, comprising a needs analysis that encompasses curriculum content, learning materials, student characteristics, and issues related to the learning process. In addition, resources needed to support product development, such as software, hardware, and distribution tools, are identified. The results of the analysis are then realized in the next stage. Previously, mathematics instruction was conducted using an ethnomathematics-based module tailored to students' needs. However, due to limited instructional time, supplementary media were needed to help students gain a deeper understanding of geometric transformations. Therefore, this Android-based learning media was developed to support the learning process and ensure that the predetermined learning targets are achieved.

The Design stage involved selecting learning materials; designing instructional content based on the ethnomathematics approach; developing a lesson plan; outlining the features; wireframing the Android-based learning media; and identifying assessment indicators to measure students' mathematical ability. The development stage involves implementing the Android-based learning media design by integrating visual, audio, text, and animation elements using the selected software. The developed product was then validated by experts and tested in a small-scale trial.

The Implementation stage involved applying the Android-based learning media in classroom instruction and conducting large-scale trials. Furthermore, the *Evaluation* stage focused on analyzing the practicality and effectiveness of the developed learning media. The expected outcomes of these stages are that the learning media will assist students in their learning process, improve their understanding of the material, and enhance their mathematical problem-solving

skills. In addition to improving problem-solving abilities, Android-based learning media are expected to strengthen students' cognitive skills, thereby contributing to improved academic achievement in mathematics.

The developed learning media include a user guide and instructional materials aligned with the core and basic competencies and the expected learning outcomes. Furthermore, the media is designed as a story-based game, allowing students to engage with mathematical concepts in a way that feels more relatable, realistic, and contextual. In the evaluation section of the learning activities, quizzes are provided to assess students' problem-solving skills through features such as drag-and-drop activities, multiple-choice, and fill-in-the-blank exercises. Additionally, a multiplayer quiz feature is available, enabling students to compete asynchronously with other users to achieve the highest score. These are structured to guide students through a more systematic sequence of mathematical problem-solving stages. The learning media also include the researcher's identity and institutional affiliation as forms of authorship acknowledgment and accountability, and to indicate the product's intellectual property ownership.

Instruments

This study employed both test and non-test instruments to evaluate the product's validity, practicality, and effectiveness. The test instruments consisted of pretest and post-test items that students were required to complete. A total of ten test items were administered to measure students' problem-solving abilities related to the given topic within a specified time limit. The test items varied in format, including multiple-choice, complex multiple-choice, and short-answer questions, all of which were constructed based on explicit Polya's problem-solving indicators: (1) understanding the problem, (2) devising a solution

plan, (3) carrying out the plan, and (4) reviewing or verifying the solution. Previous studies have indicated that objective tests, when carefully designed to reflect problem contexts, reasoning processes, and solution strategies, can assess higher-order thinking skills, including problem-solving abilities (Gottlieb et al., 2022). Each item required students not merely to recall factual knowledge but also to analyze the problem, select or construct appropriate solution strategies, and evaluate the correctness of their results (Croft et al., 2015; Gottlieb et al., 2022).

To ensure content validity, the test items were reviewed by 2 experts in mathematics education, who evaluated the relevance, clarity, and alignment of each item with the targeted indicators. The reliability analysis yielded a Cronbach's alpha coefficient of $\alpha = 0.847$, indicating high internal consistency. Additionally, split-half reliability analysis showed a correlation of $r = 0.813$ (Spearman-Brown correction), further confirming the instrument's reliability. Item-total correlation coefficients ranged from 0.654 to 0.789, demonstrating that all items adequately contributed to measuring the construct of mathematical problem-solving ability.

The non-test instruments comprised expert validation questionnaires (material and media validation) and a student practicality questionnaire. The practicality questionnaire consisted of 20 items measured on a 5-point Likert scale, assessing four aspects: (1) usefulness of learning, (2) ease of use, (3) clarity of instruction, and (4) visual appearance. Three additional items (items 21-23) were included to specifically assess students' motivation derived from gamification features (leaderboard, badges, and study time tracker).

The practicality questionnaire demonstrated excellent internal consistency with an overall Cronbach's alpha of $\alpha = 0.921$. Reliability coefficients for each subscale were as follows:

usefulness of learning ($\alpha = 0.887$), ease of use ($\alpha = 0.856$), clarity of instruction ($\alpha = 0.901$), and visual appearance ($\alpha = 0.824$). These values indicate that the instrument is highly reliable for assessing the practicality of the learning media. Construct validity was established through exploratory factor analysis, which confirmed the four-dimensional structure of the practicality questionnaire. Factor loadings ranged from 0.68 to 0.89, and the cumulative variance explained was 74.3%, indicating that the instrument adequately captured the intended constructs.

Data Analysis

The developed learning media will be evaluated based on three main criteria: 1) validity, 2) practicality, and 3) effectiveness. Therefore, specific standards are required to guide decision-making in accordance with these established criteria. The validity of the learning media was determined through expert judgment by media and materials experts; practicality was assessed through user responses; and effectiveness was measured by students' learning outcomes.

The validity of the learning media was analysed using Aiken's V index, which is appropriate for evaluating content validity based on expert judgments with a limited number of validators (Kania, 2024). Each expert assessed the learning media using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

The value of Aiken's V ranges from 0 to 1, with higher values indicating a higher level of content validity. The validity analysis was conducted for each item in the validation instrument. Furthermore, the average Aiken's V value was calculated for each assessment aspect. The interpretation of Aiken's V values is presented in Table 1 (Retnawati, 2016). The learning media were considered valid if Aiken's V value for each aspect reached at least moderate validity. If the

obtained value was below this threshold, revisions were made based on experts' suggestions.

Table 1. Interpretation of Aikens's V index

Aiken's V	Criteria
$0.8 < V < 1.00$	High Validity
$0.4 < V \leq 0.8$	Moderate Validity
$0.00 < V \leq 0.4$	Poor Validity

The practicality criteria are determined from students' responses to the learning media. The media will consider the practicality of the result if it falls within the "Good" criteria. If the results fall below this level, revisions and improvements to the media are necessary. The following section presents the classification categories used to evaluate practicality criteria.

Table 2. Practicality criteria classification

Score	Criteria
$X > X_{id} + 1,8 \times SB_{id}$	Very good
$X_{id} + 0.6 \times SB_{id} < X \leq X_{id} + 1.8 \times SB_{id}$	Good
$X_{id} - 0.6 \times SB_{id} < X \leq X_{id} + 0.6 \times SB_{id}$	Average
$X_{id} - 1.8 \times SB_{id} < X \leq X_{id} - 0.6 \times SB_{id}$	Poor
$X \leq X_{id} - 1.8 \times SB_{id}$	Very poor

Notes:

The conversion of these criteria was determined using the formula $\bar{X}_{id} = \frac{1}{2}$ (maximum (maximum score + minimum score) which represents the mean ideal score, and the formula $SB_{id} = \frac{1}{6}$ (maximum score - minimum score) which represents the ideal standard deviation. In this study, the minimum score for each validation item was 1, while the maximum score was 5.

In addition, to determine whether the developed learning media effectively enhance students' problem-solving skills, it is necessary to conduct an inferential test. Prior to conducting the inferential test, the assumption of normality for the difference scores (post-pre) was assessed using the Shapiro-Wilk test, as recommended for dependent-samples comparisons. After the data met the assumptions of normality, a paired-samples t-test was conducted; if this assumption was not met, a non-parametric test would be employed. The hypotheses to be tested are as follows:

H_0 : There is no significant effect of using Android-based learning media with an ethnomathematics approach on improving students' problem-solving abilities.

H_1 : There is a significant effect of using Android-based learning media with an ethnomathematics approach on improving students' problem-solving abilities.

■ RESULT AND DISCUSSION

This study developed Android-based learning media using the ethnomathematics approach, namely Senimatika. The philosophy behind this name reflects the idea that Senimatika serves as a bridge between two worlds often perceived as separate, namely art and mathematics. On one hand, mathematics represents order, patterns, and logical structures (Polya, 2021; Weyl, 2021). On the other hand, art embodies beauty, creativity, and cultural expression. Through Senimatika, these two domains are integrated into a dynamic learning experience where students are not only engaged in computation but also explore the deeper meanings embedded in cultural artifacts and craftsmanship, such as traditional batik patterns, traditional architecture, and indigenous games. Senimatika views mathematics not as a rigid discipline, but as a universal language capable of weaving together aesthetics and culture into a cohesive body of knowledge. Consequently,

Senimatika emerges as an educational environment characterized by joy, inclusivity, and relevance, seamlessly integrating logic and aesthetics throughout the learning process.

Senimatika features several integrated components, including learning materials, interactive quizzes, and assessments. The learning materials not only present theoretical concepts related to Geometric Transformations but also emphasize their application within traditional batik patterns provided in the lesson. Each topic on Geometric Transformations is interspersed with short quizzes that introduce the names of batik patterns and highlight sections that illustrate geometric transformations, including translation, reflection, rotation, and dilation. In addition, the learning platform offers various response formats, including multiple-choice, multiple-response, highlighting the batik pattern that indicates the correct transformation, and short-answer items. After completing all sections of the learning materials, students may take the quiz. However, the quiz becomes accessible only after students have completed all stages of the instructional sequence, ensuring that the learning process remains well-structured. The quiz comprises ten questions of different types, including single-correct-answer, multiple-correct-answer, short-answer, and identification/highlighting questions. At the end of the session, a leaderboard is displayed, showing each student's score and class ranking. The leaderboard not only assists teachers by automating quiz evaluation but also provides students with direct feedback on their performance and standing compared to their peers.

Students with the greatest score improvements tended to report that learning with Senimatika was more engaging and meaningful because it connected mathematical concepts to familiar batik patterns, which helped them visualize geometric transformations and

understand problem-solving steps more systematically. The Android-based media also provided students with flexibility to engage in independent learning and revisit the material as needed. In contrast, students whose scores declined generally expressed difficulties during the initial stage of using the application, limited time for adaptation, and a learning style preference that required more direct explanations from the teacher. Some students also perceived that the visual and cultural elements increased their cognitive load when they were not yet accustomed to linking ethnomathematical contexts with mathematical procedures.

One student stated that “the steps in the application helped me understand what to do first and what to do next when solving the problem” (S4). Another student mentioned that “learning with batik patterns made the lesson more interesting because the examples were familiar” (S7). However, one student reported that “at the beginning, there were many pictures and features, so I needed more explanation before I could focus on the mathematics” (S12). To strengthen the practicality questionnaire results, brief semi-structured interviews were conducted with several students after the implementation of Senimatika. The interview findings indicate that most students perceived the learning media as easy to use and helpful in supporting their learning process. Students reported that the clear structure of activities and step-by-step problem-solving tasks facilitated understanding of problems presented.

The integration of cultural elements was also perceived as engaging and meaningful, as it helped students relate mathematical concepts to familiar contexts. However, a small number of students reported difficulties during the initial use of the application, particularly in adapting to the digital interface and managing the amount of visual information presented. These responses suggest that while the media was generally perceived as

practical and beneficial, adequate instructional guidance and adaptation time are necessary to support all learners. Overall, the interviews indicated that *Senimatika* supports enjoyable and meaningful learning while encouraging active student engagement; however, its effectiveness is influenced by students' digital literacy readiness, the need for pedagogical scaffolding, and teacher guidance during the early phase of implementation.

Senimatika provides empirical support for multimedia learning theory, which emphasizes integrating visual and textual elements to facilitate simultaneous information processing and enhance conceptual understanding. In addition, the findings of this study are consistent with contextual learning theory, which asserts that linking learning materials to local cultural contexts makes learning more meaningful and relevant and promotes active student engagement. Furthermore, based on the results of the preliminary study and the research findings, the development of *Senimatika* not only reinforces these theories but also extends their interpretation by demonstrating that the effectiveness of multimedia- and context-based learning media is strongly influenced by supporting factors, such as the availability of adequate pedagogical scaffolding and students' digital literacy readiness. These findings indicate that the integration of culture and technology in learning must be balanced with appropriate instructional support strategies to optimize the potential of learning media.

This study has several limitations, including variation in students' digital literacy readiness, limited time for adaptation, and the need for teacher guidance during the initial phase of *Senimatika* use. In addition, while the integration of visual and cultural elements enriches the learning experience, it may increase cognitive load for some students who are not yet accustomed to linking ethnomathematical contexts with mathematical procedures. The study is also limited to a specific cultural context, namely batik

patterns, so generalization to other cultural contexts requires adaptation. Moreover, it relies on the Android platform, which restricts access for students with different devices or operating systems. These limitations underscore the importance of effective instructional support strategies and media adaptation to enhance future learning effectiveness. *Senimatika* was developed using the ADDIE model, which consists of the following stages:

Analyze

The Analyze stage in developing this learning media involved determining the material to be presented. The topic of Geometric Transformations was selected because it aligned with the research timeline and was well-suited to delivery through an ethnomathematical approach. The traditional batik patterns found in Indonesian fabrics, which represent the nation's rich cultural heritage, serve as highly contextual applications across the subtopics of Geometric Transformations (translation, reflection, rotation, and dilation) (Wesnina et al., 2025). In addition to selecting materials appropriate for the ethnomathematical approach, this stage included a needs analysis of students' learning conditions in mathematics and their existing mathematical problem-solving abilities. The goal of this process was to ensure that the learning objectives for the Geometric Transformations topic could be effectively achieved when mathematics instruction was delivered through an Android-based learning medium using an ethnomathematical approach. This collaboration exemplifies contextual mathematics learning, enabling students to grasp not only theoretical concepts but also their practical applications in everyday life.

Regarding students' initial problem-solving skills, the pretest results revealed varying levels of proficiency among the 15 participants. Seven students (46.7%) were classified in the "Very High" category, 2 students (13.3%) in the "High"

category, and 3 students (20%) in the “Moderate” category. Meanwhile, 3 students (20%) remained in the “Very Low” category, and no students were classified in the “Low” category. The overall mean pretest score was 69.20 (SD = 31.94), indicating that although the majority of students possessed relatively strong procedural problem-solving abilities, there remained notable heterogeneity in students’ initial capabilities, particularly in understanding contextual and ethnomathematical representations of problems.

Although the pretest results indicated a relatively high level of students’ mathematics problem-solving proficiency, this finding does not contradict the study’s problem formulation. As emphasized in the Introduction, the main issue addressed in this research is not students’ inability to perform mathematical procedures, but rather their difficulty in connecting mathematical concepts to real-life and cultural contexts. The pretest primarily assessed students’ procedural and routine problem-solving skills, which can be completed without meaningful engagement with contextual or ethnomathematical elements.

In contrast, the ethnomathematics-based learning proposed in this study specifically targets students’ ability to identify, interpret, and apply mathematical ideas embedded in cultural objects, such as traditional batik patterns. Classroom observations revealed that, despite achieving relatively high scores on conventional problems, many students struggled to recognize geometric transformation concepts when presented in cultural or real-world representations. Therefore, the high initial proficiency reflects procedural competence rather than the contextual and conceptual problem-solving skills that this study seeks to develop.

Design

The Design stage of developing this learning media involved planning the instructional tool,

from creating a storyboard and flowchart to developing the final Android-based application. The learning media were designed with two objectives: first, to capture students’ attention; and second, to emphasize flexibility by allowing access via individual devices. Additionally, the media was created to integrate cultural values into the learning process (Ahmad, 2024; Alam & Mohanty, 2023; Kokkinos, 2024). Furthermore, the developed media incorporates a well-structured, content-rich framework aligned with the topic of Geometric Transformations.

The subtopics presented include translation, reflection, rotation, and dilation. Beyond the mathematical underpinnings of these subtopics, the material underscores their practical applications in cultural contexts, particularly in traditional batik patterns. This approach aims to help students understand the concepts of translation, reflection, rotation, and dilation contextually through an ethnomathematical perspective. In addition to theoretical materials, practice exercises, and several interactive features were included to enhance *Senimatika*’s engagement and effectiveness as a learning tool. The following figure illustrates the design flowchart of *Senimatika*:

In addition, a blueprint was designed to guide the development of *Senimatika*. This blueprint is presented as a wireframe, a basic visual framework that illustrates the structure and layout of a digital application. It provides a simplified representation that focuses on the placement of key elements, such as navigation, buttons, and content, without incorporating visual details such as color or images. The purpose of the wireframe is to visualize the functionality and user flow before progressing to a more detailed visual design. The wireframe design is presented as follows:

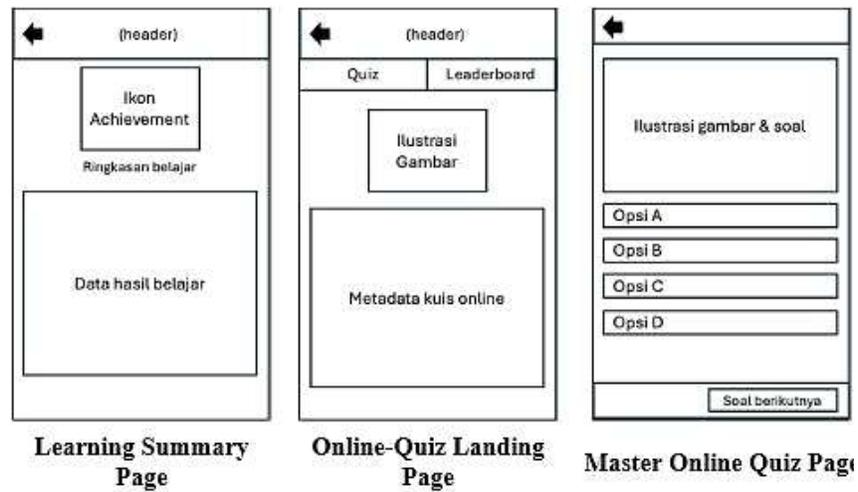
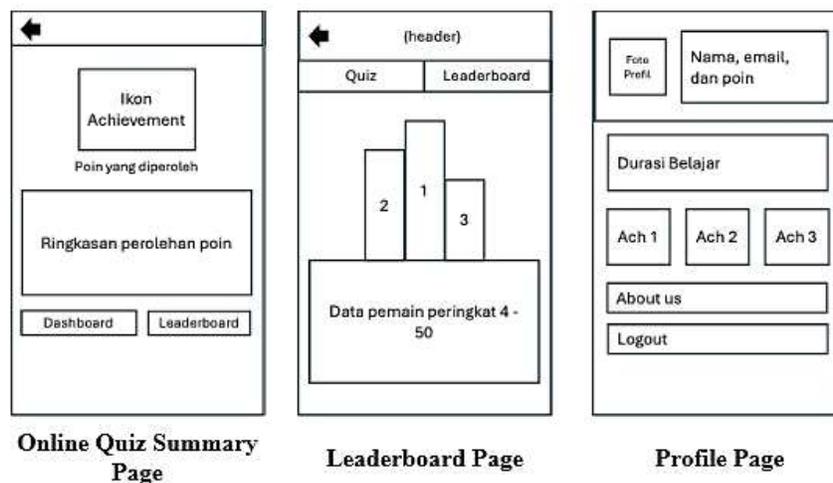


Figure 5. Wireframe of learning summary page, online-quiz landing page, and master online quiz page



Notes: Ach 1, Ach 2, Ach 3 = List of badges that have been earned

Figure 6. Wireframe of online quiz summary page, leaderboard page & profile

In terms of features within the app, Senimatika was structured to incorporate several supporting features, including a leaderboard, a study time tracker, and badges. These features were intentionally designed as motivational and self-monitoring components, rather than as analytical variables within the present study. The leaderboard displays accumulated scores from asynchronous multiplayer quizzes, while the study time tracker enables students to monitor the total duration of their interaction with the application. In addition, the badge system represents

students' progression within the app, ranging from "Explorer", "Beginner", "Professional", "Scientist", "Math Magician", "Mathematics Expert", to "Mathematical Genius". Collectively, these features function as design affordances to encourage engagement and interaction with the learning media.

Development

The Development stage of creating this learning media involved implementing the design developed in the previous phase and conducting

validation with material and media experts to obtain feedback to improve and refine product. A total of three material experts and three media experts were asked evaluate the learning media.

Based on the validation results analysed using Aiken's V index, the learning media *Senimatika* demonstrated a moderate level of validity. The validation conducted by material experts showed that the content quality and objectives dimensions obtained an Aiken's V value of 0.89. In contrast, the instructional quality

aspect achieved a value of 0.90, placing it in the "High Validity" category. Meanwhile, validation by media experts indicated that content quality and objectives, as well as instructional quality, yielded Aiken's V values of 0.77 and 0.78, respectively, which are categorized as "Moderate Validity". These results indicate that *Senimatika* meets the validity criteria for instructional use. In addition to the quantitative validation results, experts also provided suggestions for improving the learning media.

Table 3. Suggestions from media experts

Experts	Suggestions
Expert 1	As a learning medium, it is appropriate to give it a name; therefore, the name "Senimatika" was chosen. The philosophy of <i>Senimatika</i> in geometry transformation learning media is rooted in the view that mathematics is not merely a system of symbols and procedures but a visual and spatial language with an inherent affinity for art. Geometric transformations such as translation, reflection, rotation, and dilation represent mathematical expressions of motion, symmetry, balance, and changes in form, concepts that also lie at the core of visual art and design.
Expert 2	Adding practice problems related to batik patterns and cultural elements so that they are relevant to the topic and the approach that has been implemented. The focus is not only on abstract mathematical symbols but also aligns with the cultural approach being adopted. This is intended to guide students in solving mathematical problems in a more engaging, coherent, and structured manner, thereby enabling them to develop mathematical construction abilities in problem solving.
Expert 3	Need to provide students with instructions using engaging language so that they can follow the guidelines properly.

Table 4. Suggestions from material experts

Experts	Suggestions
Expert 1	The inclusion of culturally grounded contextual problems enables students to visualize and solve them using the developed application.
Expert 2	Completed practice exercises can be sent to the teacher's email address for review and assessment as part of the evaluation process.
Expert 3	The batik pattern images provided are further enriched to enable students to become familiar with a variety of batik cultures and to identify geometric transformation patterns within the batik designs.

These suggestions served as the basis for revisions prior to further implementation.

Implementation

In the Implementation stage, Android-based learning media using an ethnomathematics

approach were used during the learning activities for the topic Geometric Transformations, which included the subtopics Translation, Reflection, Rotation, and Dilation. The implementation was conducted over three instructional meetings, within the regular mathematics class schedule.

At this stage, both teachers and students installed the *Senimatika* application on their respective devices, created new accounts that required an active email address, and used the learning media accordingly. The researcher provided a brief orientation to the application’s main features and explained how the media would be used to support learning activities. During the learning process, the researcher served as a facilitator, guiding students, clarifying instructions, and encouraging discussion. In contrast, students independently explored the learning materials, completed interactive tasks, and worked on problem-solving activities embedded in the application. The classroom teacher remained present to maintain order but did not provide direct instructional intervention on the content.

Teachers and students explored all available features, followed every instruction provided in

the application, and completed one topic within *Geometric Transformations*. Additionally, students were allowed to restart from the beginning if they needed further reinforcement of the material. They were also encouraged to share the learning media with peers from other schools so that more students could experience and benefit from using *Senimatika*.

Evaluation

Practicality Evaluation

Practicality was assessed using a 15-item Likert-scale questionnaire with responses ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The total scores were normalized to overall scores on a 20-100 scale, with 100 representing the maximum practical score. The results showed an average score of 85.86, which falls within the “Very Good” category.

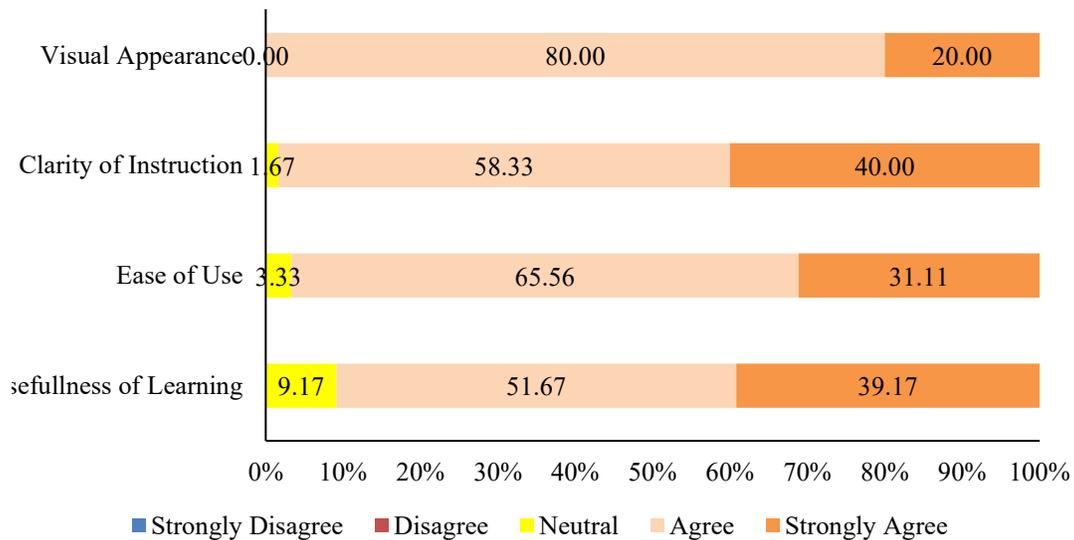


Figure 7. Distribution of students’ responses across practicality aspects

The visualization in Figure 7 indicates that most students selected “Agree” or “Strongly Agree” across all aspects of practicality. The Visual Appearance aspect received the highest positive response rate (100% positive), followed by Clarity of Instruction (98.33%), Ease of Use (96.67%), and Usefulness of Learning (90.83%). The limited number of neutral responses in the

Usefulness aspect suggests that some students may require brief initial guidance when using the learning media.

To strengthen the practicality questionnaire results, brief semi-structured interviews were conducted with several students after the implementation of *Senimatika*. Students reported that the clear structure of activities and step-by-

step problem-solving tasks facilitated understanding of the problems presented. The integration of cultural elements was perceived as engaging and meaningful, as it helped students relate mathematical concepts to familiar contexts. One student stated, "The steps in the application helped me understand what to do first and what to do next when solving the problem" (Student S4). Another mentioned, "Learning with batik patterns made the lesson more interesting because the examples were familiar" (Student S7).

Gamification Features and Student Motivation

Although the leaderboard, study time tracker, and badge features were designed as

motivational and self-monitoring components rather than primary analytical variables, qualitative evidence from student interviews and supplementary questionnaire items provides insights into their perceived motivational impact. Semi-structured interviews with five students revealed positive perceptions of the gamification features.

Three additional questionnaire items (items 21-23) were administered to assess students' perceptions of gamification features' motivational impact:

These findings suggest that, although gamification features were not the primary focus of this study's analytical framework, students perceived them as contributing positively to

Table 5. Students' response to the gamification features

Student	Response
S4	"The leaderboard feature motivated me to complete more problems and check my ranking daily."
S7	"Earning badges made learning more enjoyable and gave me a sense of achievement."
S9	"The study time tracker helped me realize how much time I spent learning each topic."
S11	"I felt more engaged because I could see my progress through the badge system."
S12	"The leaderboard added a fun, competitive element that made me want to improve my score."

Table 6. Students' response to gamification features' motivational impact

Item	Statement	Mean Score	Percentage
21	"The leaderboard feature motivated me to complete more problems and check my ranking daily."	4.27/5.00	86.7%
22	"Earning badges made learning more enjoyable and gave me a sense of achievement."	4.13/5.00	80.0%
23	"The study time tracker helped me realize how much time I spent learning each topic."	4.20/5.00	83.3%

engagement and motivation. Future research could systematically analyze application log data (e.g., leaderboard check frequency, badge accumulation patterns, study duration) to provide more robust empirical evidence of the effectiveness of these features.

Effectiveness Evaluation

Effectiveness was evaluated by comparing pre- and post-test scores on problem-solving skills. Following the media use, post-test results indicated improved performance among most students. Eight students (53.3%) were

categorized as “Very High,” 2 students (13.3%) as “High,” and 2 students (13.3%) as “Moderate.” However, 2 students (13.3%) remained in the “Very Low” category, and 1 student (6.7%) was classified in the “Low” category. The mean post-test score increased to 83.71 with a standard deviation of 17.37, representing a gain of 14.51 points from the pretest mean.

This distribution suggests that although the majority of students achieved higher levels of mathematical problem-solving ability after engaging with ethnomathematics-based digital learning media, the improvement was not uniform across learners. The persistence of students in

the lower categories indicates that the effectiveness of culture-based digital learning media is influenced by students’ learning readiness, their ability to adapt to digital learning environments, and the extent of pedagogical scaffolding provided during the learning process.

The four stages of mathematical problem solving proposed by Polya were analyzed to provide a deeper understanding of students’ abilities across each problem-solving indicator. The radar chart (Figure 8) reveals differential improvement across Polya’s four problem-solving indicators. The greatest improvement was observed in “Devising a Solution Plan” (+17.1%), suggesting that Senimatika’s structured problem-

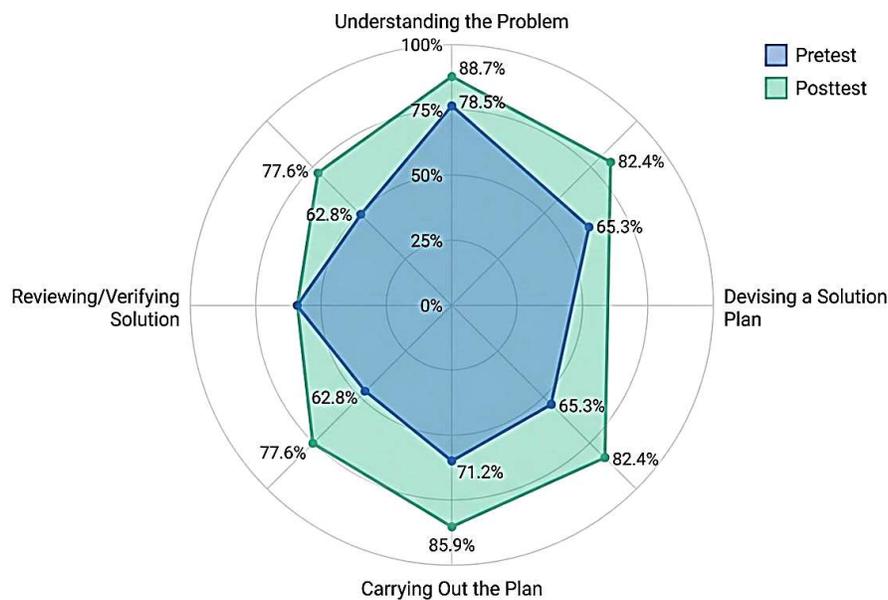


Figure 8. Students’ performance on polya’s problem-solving indicators

solving scaffolding effectively supported students’ strategic planning abilities. This finding aligns with Senimatika’s design features, which provide explicit guidance and cultural contexts (batik patterns) that help students visualize and formulate solution strategies. In contrast, the “Reviewing/Verifying Solution” indicator showed the smallest gain (+14.8%), suggesting that students may require additional pedagogical support to develop metacognitive monitoring skills. This suggests that

future iterations of Senimatika could benefit from incorporating more explicit prompts and reflective activities to strengthen students’ self-evaluation and verification processes.

In the first indicator (Understanding the Problem), most students adequately stated the relevant information; however, some students copied the information directly without demonstrating an understanding of the relationships among concepts. In the second

indicator (Devising a Solution Plan), students' abilities were reflected in the accuracy with which they selected appropriate formulas, strategies, or approaches, and performance variations became more apparent in contextual problems that required integrating mathematical concepts with cultural contexts. The third indicator (Carrying Out the Plan) indicated that most students performed calculations correctly, although procedural errors were still observed in several responses. In the fourth indicator (Reviewing or Checking the Solution), students' performance was relatively low because many did not consistently recheck their final answers, allowing simple errors to go undetected.

The Shapiro–Wilk test indicated that the difference between pretest and post-test data was not normally distributed. This conclusion was supported by results obtained using statistical software, which show that, $W = 0.8219$ with $p - \text{value} = 0.00712$. When compared with the critical value W_{table} from the Shapiro–Wilk table at $n = 15$ and a significance level of, $\alpha = 0.05$ it was found that $W_{\text{calculated}} < W_{\text{table}}$ ($0.8219 < 0.881$) and $p - \text{value} = 0.00712$. These results indicate that H_0 was rejected, meaning that both pretest and post-test data did not meet the normal distribution assumption. This condition could be attributed to the small sample size (15 students), which makes deviations from normality easier to detect. Additionally, the presence of extreme values or outliers in the results, where a few students scored very high or very low, may also have contributed to the non-normal distribution of the pretest and post-test data, reflecting significant variations in student ability levels.

Based on the results of the normality test, the data were not normally distributed. Therefore, a hypothesis test was conducted using the Wilcoxon Signed-Rank Test. This test aims to determine whether there is a significant difference between two paired data sets, specifically the

pretest and post-test scores. According to the result of the test, the calculated V -value was 22, with p -value was 0.03105. Cohen's d was also calculated and classified as a moderate effect ($d = 0.557$). This finding indicates a significant difference between pretest and posttest scores, suggesting that the developed learning media have the potential to improve students' problem-solving skills.

In addition to the improvement observed between pretest and posttest scores, the effectiveness of the developed learning media was further assessed using the N-Gain value. The average pretest score (X) was 69.20, while the average post-test score (Y) was 83.71. Using the N-Gain formula, the result was 0.4711, which falls in the moderate category according to the N-Gain classification table. This finding indicates that Android-based learning media employing an ethnomathematics approach is moderately effective in enhancing students' learning outcomes. In practice, teachers can maximize the benefits of this medium by integrating it into lessons on geometric transformations once students have been introduced to the basic concepts, as it helps reinforce understanding through visual and cultural representations. This media is particularly suitable for blended learning, where students can independently explore the material through the application and then discuss their findings and problem-solving strategies in class. Teachers are advised to provide guiding questions or brief demonstrations during the initial use of the media to support students with lower digital literacy. Additionally, the media can be utilized in formative assessments by assigning specific tasks or quizzes within *Senimatika*, allowing teachers to monitor students' progress and provide targeted feedback. By aligning the use of this medium with classroom instruction and providing structured guidance, teachers can enhance both engagement and conceptual understanding while connecting mathematical concepts to their cultural contexts.

Despite the statistically significant difference between the pretest and post-test scores and the moderate effect size, the magnitude of learning gains observed in this study was influenced by several contextual factors. One of the main factors was the relatively high initial ability of the students in procedural and routine problem-solving. The pretest results showed that 7 out of 15 students were categorized as having very high ability, indicating that most students had already mastered the basic concepts prior to the implementation of the developed learning media. Under such conditions, the potential for further score improvement becomes more limited, which may explain why the increase in post-test scores was not substantial and why the N-Gain value remained in the moderate category.

In addition, the limited time available for implementing the ethnomathematics-based learning media may have affected the depth of students' conceptual understanding. Several national holidays and school activities coincided with the class schedule, resulting in the postponement of two learning sessions. These interruptions created relatively long intervals between learning topics, which may have reduced continuity and caused students to partially forget previously learned material. Consequently, these factors likely contributed to the moderate effect size and N-Gain outcomes observed in this study.

■ CONCLUSION

Using the ADDIE model, this research described the creation, implementation, and qualitative evaluation of *Senimatika*, an Android-based ethnomathematics application for Geometric Transformations, applied to junior secondary school students. *Senimatika* was rated "High Validity" and "Moderate Validity" by experts in the material and media domains, respectively, satisfying the criteria for validity and suitability for classroom practice according to their user ratings. The "Excellent" ratings in the

practicality assessments further corroborated that the *Senimatika* was well-designed, easy to use, and enabled students to grasp the learning material. Based on the effectiveness test results, there was improvement in students' mathematical problem-solving skills after using *Senimatika*, as shown by the significant difference between pretest and post-test scores, Cohen's *d* effect size, and an N-Gain value of 0.47, categorized as moderate. The integration of Android-based learning media with local cultural contexts is an effective strategy for enhancing student participation, fostering a deeper, more contextual understanding of geometric transformation concepts, and supporting the development of mathematical problem-solving competencies.

From the perspective of deep learning, which underpins the 2025 Curriculum, *Senimatika* demonstrates strong alignment with the principles of joyful, meaningful, and mindful learning. The interactive visualizations and cultural contexts embedded in the media create an engaging learning experience in which students can actively explore geometric transformation concepts through dynamic, aesthetic representations, rather than merely engaging in mechanical procedural exercises. Such enjoyable learning experiences play an important role in increasing students' motivation and learning engagement. Furthermore, the integration of ethnomathematical elements promotes meaningful learning, as students can connect abstract geometric concepts with cultural patterns and visual phenomena closely related to their daily activities. This connection helps students build deeper conceptual understanding, so that learning does not stop at memorizing formulas but progresses toward the internalization of mathematical meaning and structure. In addition, *Senimatika* also supports mindful learning by encouraging students to observe, reflect on, and reason about the transformation processes they perform digitally. The exploratory nature of media fosters awareness of thinking processes,

deliberate decision-making, and reflective problem-solving, which are key characteristics of deep learning.

Despite the overall positive outcomes of the study, the findings also indicate that two students experienced declines in post-test scores. This suggests that the benefits of ethnomathematics-based digital learning media may not be experienced uniformly by all learners, particularly those who require more time to adapt or more explicit instructional guidance. The richness of cultural and visual elements, while engaging many students, may pose additional cognitive demands for some learners when adequate scaffolding is not provided. This nuanced finding highlights the importance of pedagogical scaffolding and teacher facilitation during the early stages of implementation. The observed decrease in scores among a small number of students may be attributed to several interrelated factors. The integration of rich visual and cultural elements, while beneficial for many learners, may increase extraneous cognitive load for some students, thereby reducing their focus on mathematical reasoning. Differences in digital readiness and the need for longer adaptation time may also have affected students' ability to use the learning media effectively.

Future research is encouraged to employ quasi-experimental or experimental designs with control or comparison groups to more rigorously examine the contribution of Senimatika beyond pretest–post-test improvements. Given the facilitated nature of the present implementation, subsequent studies should investigate the effectiveness of the media when implemented independently by classroom teachers to minimize potential researcher effects. In addition, extending the duration of the intervention may provide deeper insights into learning retention and conceptual transfer over time.

From an inclusivity perspective, future studies are recommended to explore the

applicability of Senimatika for students with special educational needs. The current study was limited to students who could independently interact with Android-based learning media, as the application's current version does not yet incorporate accessibility features, such as adaptive interfaces or assistive technologies. Therefore, future development should integrate Universal Design for Learning (UDL) principles to ensure broader accessibility and more inclusive ethnomathematics-based digital learning environments.

■ **DECLARATION OF GENERATIVE AI USAGE IN THE WRITING PROCESS**

During manuscript preparation, the authors used ChatGPT (OpenAI) and Grammarly to assist with language refinement, grammar checking, and proofreading. The authors have reviewed and edited all content generated by these tools and assume full responsibility for the content of the published article.

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