

Development of ethnomathematics-integrated android-based media for enhancing problem-solving skills in secondary geometry learning

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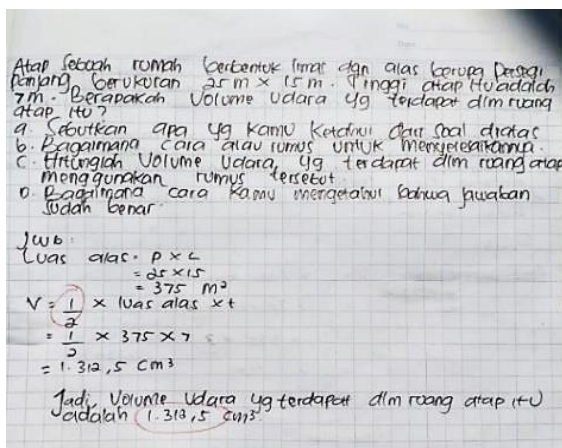
ABSTRACT

Mathematical problem-solving abilities among junior high school students remain persistently underdeveloped, particularly in geometry instruction on prisms and pyramids, which frequently proceeds without interactive or culturally responsive media. Although interest in ethnomathematics-informed digital tools continues to grow, empirical evidence directly linking Android-based applications grounded in local cultural heritage to measurable gains in problem-solving at this level remains scarce. This study developed an Android-based m-learning medium integrating ethnomathematical elements into prism and pyramid instruction to enhance eighth-grade students' mathematical problem-solving skills. The 4D Model (Define, Design, Develop, and Disseminate) was applied, and a small-scale pilot trial was conducted involving ten eighth-grade students at one of state secondary schools in Pontianak. Expert appraisal yielded a composite validity score of 95.33%, practitioner and learner evaluations produced a practicality rating of 93.95%, and effectiveness testing revealed a statistically significant improvement, with mean scores rising from 51.11 at pretest to 90.83 at posttest ($p = 0.00000034$; Cohen's $d = 3.09$). The integration of local cultural artefacts—notably ketupat, patlau, and pengkang—effectively bridged abstract geometric concepts with students' everyday experiences. Given the pilot nature of this study, the findings should be regarded as preliminary and not yet generalisable. Future research is encouraged to involve larger, more diverse samples and to employ controlled experimental designs to validate these outcomes more rigorously.

INTRODUCTION

The mathematical problem-solving skill is one of the objectives of mathematics learning listed in the curriculum. Based on these objectives, mathematical problem-solving skills are part of the independent curriculum and should be considered in the learning process. Mathematical problem-solving skills are among the essential competencies for students learning mathematics (Amalina & Vidákovich, 2023; Nugraheni & Marsigit, 2021; Olivares et al., 2021). This skill falls under the category of higher-order thinking skills (HOTS), which need to be developed (Hodiyanto & Firdaus, 2020; Miri et al., 2007). However, studies have shown that students experience difficulties in solving problems related to mathematical problem-solving (Hodiyanto & Firdaus, 2020; Risnawati et al., 2018; Salemeah & Etchells, 2016), and students' mathematical problem-solving skills are still

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Translation: The roof of a house is shaped like a pyramid with a rectangular base measuring 25 m × 15 m. The height of the roof is 7 m. How much air volume is contained in the roof space?

- State what you know from the problem above!
- What method or formula would you use to solve it?
- Calculate the air volume contained in the roof space using the formula!
- How do you know that your answer is correct

Answer:

Base area = $l \times w = 25 \times 15 = 375 \text{ m}^2$

$V = \frac{1}{3} \times \text{base area} \times \text{height} =$

$= \frac{1}{3} \times 375 \times 7$

$= 1,312.5 \text{ cm}^3$

Therefore, the air volume contained in the roof space is $1,312.5 \text{ cm}^3$

Figure 1. Example of Students' Answer

classified as low (Salam et al., 2024; Wahyuni, et al., 2025). One cause of this low skill is the suboptimal use of learning media, especially Android-based learning media (Yani et al., 2022). Next, the researchers conducted a preliminary study in one of the public junior high schools in Pontianak.

The results of an interview with a mathematics teacher at one of state secondary schools in Pontianak, West Kalimantan, Indonesia, revealed that students continue to struggle with solving mathematical problems, particularly those related to pyramids. To strengthen the interview results, the researchers administered a mathematical problem-solving skill test to one class of ninth-grade students at one of secondary schools Pontianak who had studied the pyramid material, and the average score obtained was 28.28. They then selected a sample of students' answers, which are presented in Figure 1.

Based on the pre-assessment results shown in Figure 1, students did not initially understand the information provided in the problem and the questions posed. Students also made mistakes in determining the correct formula to use, resulting in incorrect calculations. The students' answers indicate a lack of problem-solving skills, as they struggled to understand the information provided and the information required in the problem. Additionally, students made mistakes in selecting the correct formula and failed to double-check their answers, which ultimately affected their calculations and the accuracy of the final results.

Furthermore, interviews with teachers at one of state secondary schools in Pontianak revealed that one of the causes of students' low mathematical problem-solving skills is the inadequate media used in mathematics learning. Mobile phones are used to support the learning process through WhatsApp groups and Google Classroom, which serve as media for delivering learning materials. Mobile phones are primarily used to share information rather than to enhance students' mathematical problem-solving skills. Teachers at school have used m-learning, but it has not yet been optimised, so it has not yet improved students' problem-solving skills. Moreover, mathematics is an abstract subject, so interactive media are needed to help students understand these concepts more easily. The use of appropriate media in the learning process can help students visualise abstract mathematical concepts (Lapele & Papalia, 2025). One learning media that can be developed is m-learning, which utilises smartphone/Android technology (Amsyar et al., 2022). *M-learning* is a form of learning that can be done anywhere, by anyone, and at any time, making it easy for students to acquire knowledge (Naveed et al., 2023; Qazi et al., 2024). Additionally, the Systematic Literature Review provided recommendations for developing smartphone- and Android-based learning media to enhance mathematical problem-solving skills (Teapon & Kusumah, 2023).

Although a growing body of research has developed mobile learning (m-learning) media in mathematics learning (Apricillia et al., 2024; Fabian et al., 2018; Fahmi & Qohar, 2023; Jelatu et al., 2019; Murtiyasa et al., 2020), these initiatives were not explicitly oriented toward developing problem-solving skills. Yani et al. (2021) developed an Android-based m-learning medium for

mathematics, yet their work did not incorporate ethnomathematical content, leaving a gap in culturally grounded mobile learning for problem-solving. Previous research also found that ethnomathematics-based mathematics modules are effective in improving problem-solving skills (Andang, Sowanto, Hadi, et al., 2025). In that study, the medium took the form of a module, whereas the present study develops an Android-based m-learning application. To date, no study has systematically developed Android-based m-learning media that draws specifically on Pontianak's local cultural heritage—such as ketupat, patlau, and pengkang—to cultivate problem-solving skills in geometry. Firdaus and Hodiyanto (2019) and Hodiyanto et al. (2022) found that many traditions or cultures in West Kalimantan contain mathematical elements that can be utilised in the learning process, as well as the potential to integrate digital cultural media into mathematics education in Indonesia (Sunzuma & Umbara, 2025). This gap becomes even more evident when considered alongside the broader ethnomathematics literature.

In the broader literature, integrating ethnomathematics into digital learning environments has shown considerable promise across diverse educational contexts. Most studies confirm that the integration of ethnomathematics into Android-based or digital media can enhance students' mathematical problem-solving abilities, engagement, and cultural appreciation across various educational levels and cultural contexts (Andang, Sowanto, & Hadi, 2025; Andang, Sowanto, Hadi, et al., 2025; Novitasari & Walid, 2022). Some studies also explore augmented reality and interactive media, further supporting the potential of technology-enhanced ethnomathematics learning (Jampel & Antara, 2025). While these findings collectively affirm the pedagogical value of ethnomathematics, a critical gap persists: no prior study has integrated ethnomathematics drawn from Pontianak's local culture into an Android-based m-learning platform specifically designed to foster problem-solving skills. The gap in the literature regarding integrating ethnomathematics into Android-based learning media to improve students' problem-solving skills stems from a lack of robust, empirical evidence linking ethnomathematics, Android-based learning media, and problem-solving skills. The direct, empirical link and the in-depth mechanism by which a specific Android-based ethnomathematics application enhances problem-solving remain areas requiring further focused investigation. The present study directly addresses this gap by designing and developing an Android-based m-learning platform that integrates Pontianak's ethnomathematical heritage to cultivate students' mathematical problem-solving skills.

This study is directed toward three principal objectives. The first objective seeks to examine the extent to which the Android-based interactive m-learning media embedded with ethnomathematics elements fulfil the validity criteria as an instructional tool designed to cultivate mathematical problem-solving skills in geometry learning, particularly on the topics of prisms and pyramids. The second objective is to investigate the extent to which the developed media are practical when deployed in real classroom settings to facilitate learners' mathematical problem-solving skills in geometry, specifically prisms and pyramids. The third objective aims to evaluate the extent to which the Android-based interactive m-learning media with ethnomathematics integration is effective in fostering and strengthening mathematical problem-solving competencies among learners throughout the geometry learning of prisms and pyramids. In alignment with these objectives, the following research questions are posed: (1) To what extent does the Android-based interactive m-learning media with ethnomathematics integration satisfy the validity standards required for enhancing mathematical problem-solving skills in geometry learning of prisms and pyramids? (2) In what manner does the developed media exhibit practicality in supporting learners' mathematical problem-solving skills during geometry learning of prisms and pyramids? (3) To what degree is the Android-based interactive m-learning media with ethnomathematics integration regarded as effective in nurturing mathematical problem-solving competencies within geometry learning of prisms and pyramids?

METHODS

This study adopted a Research and Development (R&D) approach to develop an interactive Android-based Mobile Learning (M-Learning) medium that incorporates ethnomathematics using the Smart Apps Creator (SAC) platform for geometry topics on prisms and pyramids. The

Table 1
Instrument validation results

Instrument Type	Evaluated Aspects	Average score (%)	Category
Mathematical Problem-Solving Test	Indicator relevance, clarity of language, cultural context, and conceptual accuracy	91.8	Very Valid
Teacher and Student Response Questionnaire	Clarity of statements, relevance to media use, and ease of response	90.7	Very Valid

Table 2
Results of empirical validity and reliability

Item Number	Validity	Reliability
1	0.95	0.78
2	0.94	
3	0.96	
4	0.96	

development framework applied was the Four-D Model (4D) introduced by Thiagarajan et al. (1974), comprising four sequential stages: Define, Design, Develop, and Disseminate. This model was selected for its systematic, structured nature, ensuring that the resulting product meets the criteria of validity, practicality, and effectiveness required for meaningful classroom application. It should be noted that the Disseminate stage was only partially executed owing to research time constraints; specifically, only the packaging and limited dissemination sub-stages were completed, while broader field validation testing is proposed as a direction for future research.

The *Define* stage aimed to determine and specify the learning needs. This stage included several analyses. The *front-end analysis* was conducted to identify problems in mathematics learning, particularly in the topic of solid figures (prisms and pyramids). The *learner analysis* examined students' characteristics, prior knowledge, and motivation for learning mathematics. The *task analysis* identified the essential competencies to be mastered, including identifying elements, calculating the surface area and volume of prisms and pyramids, and applying these concepts to real-world contexts. The *concept analysis* explored the interrelation of geometric concepts and identified opportunities to integrate local cultural elements. Based on these analyses, the *instructional objectives* were specified to ensure that the learning process aligned with learners' needs. This stage was analytical and conceptual, serving as the foundation for subsequent media design.

The *Design* stage aimed to translate the analytical findings into a concrete instructional product. Three primary activities were undertaken during this stage. First, *research instruments* were developed, including a mathematical problem-solving skill test to assess the effectiveness of the media, expert validation sheets to evaluate the validity of the media, and teacher and student response questionnaires to measure the practicality of the media. The problem-solving skill test consisted of four essay items, each constructed based on Polya's problem-solving indicators: understanding the problem, devising a plan, carrying out the plan, and looking back. Each item carried a maximum score of 12 points. Content validity of the instruments was examined through expert review, and reliability was assessed using Cronbach's alpha to ensure internal consistency. The instruments were validated by two material experts and one educational evaluation expert prior to use. Validation assessed indicator suitability, clarity of wording, cultural relevance, and alignment with learning objectives. The validation results indicated that all instruments achieved a very high level of validity, as presented in Table 1.

The average score of 91.25% indicates that all instruments were highly valid and suitable for use in the development stage. The validators suggested simplifying some question wordings and increasing the variety of cultural contexts to make the instruments more representative of students' real-life experiences. Furthermore, the results of the empirical validation and reliability analyses for the four problem-solving skill test items are shown in Table 2.

Table 3
Item distribution of expert validation and response questionnaire

Instrument	Dimensions / Aspects	No. of Items	Scale
Media Validation Sheet (17 items)	Effects on learning strategy (3 items)	3	5-point
	Software engineering (8 items)	8	Likert (1-5)
	Visual display (6 items)	6	
Material Validation Sheet (17 items)	Content feasibility (2 items)	2	5-point
	Material organisation (4 items)	4	Likert (1-5)
	Evaluation and exercise quality (5 items)	5	
	Language appropriateness (3 items)	3	
	Effects on learning strategy and assessment (3 items)	3	
Teacher Response Questionnaire (11 items)	Relevance to instructional materials (2 items)	2	5-point Likert (1-5)
	Alignment with learning content (2 items)	2	
	Application efficiency (2 items)	2	
	Ease of operation (2 items)	2	
	Application attractiveness (3 items)	3	
	Student Response Questionnaire (14 items)	Software engineering (2 items)	2
	Instructional design (7 items)	7	Likert (1-5)
	Visual communication (5 items)	5	

Table 2 shows that each test item has a validity value (correlation coefficient) above 0.9, indicating that each item is highly valid. In addition, the instrument has a reliability coefficient of 0.78, indicating it is reliable and consistent in measuring the intended construct. The empirical validity and reliability of the questionnaire are not provided, as it is intended to assess the practicality of the media; these will be established after a small-scale trial. Although four test items were initially developed and empirically validated, only three were retained as the final research instrument. The three retained items were deemed sufficient to comprehensively measure students' mathematical problem-solving competencies across the targeted learning objectives. The structure and item distribution of the expert validation sheets for media and the response questionnaire are presented in Table 3. Each instrument was rated using a five-point Likert scale ranging from 1 (very poor) to 5 (very good).

Second, the *selection of media and format* involved choosing *Smart Apps Creator* (SAC). SAC was selected as the development platform for its ability to produce Android applications that are accessible offline and feature engaging visual displays, without requiring specialised programming expertise. Third, an *initial product design* was constructed, encompassing the media layout, navigational structure, and learning content—including concept introductions, contextual exercises, self-evaluation activities, and the integration of ethnomathematical elements drawn from Pontianak's local culture, such as *ketupat*, *patlau*, and *pengkang*. The media was structured around seven sequential sections: (1) Instruction, providing orientation to the application and guiding students on how to navigate and operate each available feature; (2) Profile, presenting information about the developer and the academic context in which the media was developed; (3) Learning Objectives, outlining the Core Competencies and Achievement Indicators aligned with the national curriculum, ensuring students understand the expected learning outcomes before engaging with the main content; (4) Material, presenting concepts of prisms and pyramids through text, images, and 3D animations, with ethnomathematical examples embedded throughout; (5) Video, providing supplementary audio-visual content to reinforce students' conceptual understanding of prisms and pyramids, while accommodating visual and auditory learning styles; (6) Exercises, offering contextual problem-solving tasks grounded in local cultural artefacts; and (7) Quiz, comprising a self-assessment quiz with immediate corrective feedback. The learning flow was designed to guide students sequentially from the Instruction section through to Evaluation, with "Next" and "Back" navigation buttons on each page. A Home button was also included on every screen to allow non-linear navigation when needed. The interface adopted a dominant soft blue and orange colour

scheme, selected to create a cheerful and stimulating visual environment appropriate for junior high school students. All content was designed to run offline on Android devices, ensuring accessibility regardless of internet connectivity.

The *Develop* stage aimed to produce a feasible and high-quality learning product through expert validation, revision, and limited trials. During the expert appraisal, the media were evaluated by three material experts and three media experts to assess content accuracy, visual design, language, and the integration of ethnomathematical elements. Based on their suggestions, several revisions were made to improve the product's readability and usability. Subsequently, a developmental test was conducted involving one mathematics teacher and ten eighth-grade students to obtain data on the practicality and effectiveness of the media. The data obtained from this stage were analysed to determine the product's feasibility, and the results are presented in the *Results* section.

The *Disseminate* stage aimed to introduce and distribute the developed media to potential users. Due to the limited research duration, only two sub-stages were completed: *packaging* (final product refinement) and *diffusion and adoption* (limited dissemination). In the *Packaging* sub-stage, the product was refined based on expert validation and trial results, including improving the interface, navigation, and user guidelines. In the *diffusion and adoption* sub-stage, the product was disseminated to mathematics teachers through a brief training session and classroom implementation support. The Validation Testing (Wider Field Testing) sub-stage was not conducted and is recommended for future research to examine the product's feasibility on a broader scale.

The research subjects consisted of three material expert validators, three media expert validators, one mathematics teacher, and ten eighth-grade students. The subjects were selected purposively based on their involvement in the learning process and product development. The sample in this study consisted of students who had already learned plane geometry but had not yet studied solid figures (prisms and pyramids), and who were willing to participate as research subjects. The sample included only 10 students because the study was still in a small-scale trial phase, allowing it to be continued later on a larger scale. Data were analysed using descriptive quantitative and qualitative techniques. Quantitative analysis was used to calculate the average scores of validity, practicality, and effectiveness.

The media were considered valid if the average score was at least 81%; they fell into the *very valid* category and had been revised in accordance with the validators' suggestions. The media were considered practical if the average score reached at least 81% and were deemed easy to use by both teachers and students without significant difficulties. Furthermore, the media were considered effective if the average student learning outcomes increased and at least 65% of students achieved a score ≥ 80 (the Minimum Mastery Criterion) (Hodiyanto et al., 2020). Furthermore, the medium is considered effective if students' posttest mathematical problem-solving skills are better than their pretest skills. The pretest and posttest results were compared using a paired t-test in Excel, after the data were confirmed to be normally distributed by the Lilliefors test.

FINDINGS

Define Stage

The define stage aims to identify and analyse the fundamental needs and problems that serve as the basis for developing the learning media. According to Thiagarajan, Semmel, and Semmel (1974), this stage comprises five main activities: *front-end analysis*, *learner analysis*, *task analysis*, *concept analysis*, and *the specification of learning objectives*.

Front-end analysis: This analysis was conducted to identify the initial learning conditions and existing problems in mathematics instruction. Based on interviews and classroom observations at school, the learning process was still dominated by textbook use and teacher explanations, with little support from interactive media. Teachers had never utilised Android-based learning media, while students found it challenging to understand the properties of three-dimensional shapes because the materials were presented only in two dimensions. Teachers also emphasised the need for learning media that could link mathematical concepts to local culture, thereby making learning more contextual and meaningful for students.

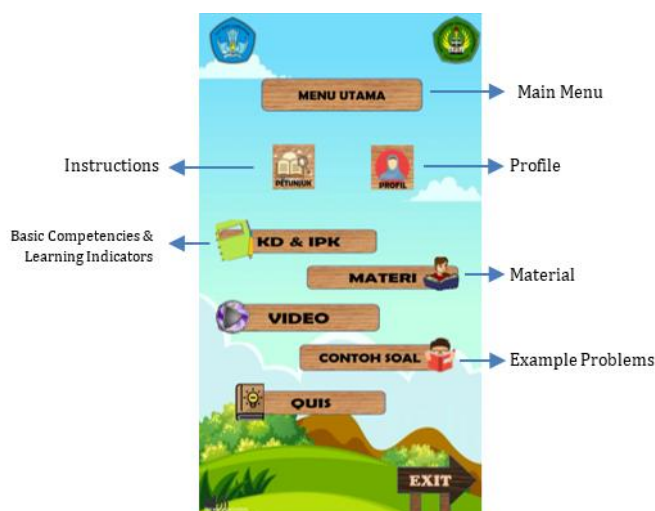


Figure 2. Main Menu Display of the Learning Media

Learner analysis: This analysis examined students' characteristics, skills, and learning needs. Based on the interview results and classroom observations, most students already owned Android devices and were familiar with them. They showed strong enthusiasm for technology-assisted learning but had not previously engaged with mathematical applications. Students expressed greater interest in learning through visual and interactive formats rather than through lengthy text-based explanations.

Task analysis: This analysis was conducted to identify the competencies that students are expected to acquire based on the curriculum. Based on the learning outcomes at the junior high school level, for the topic of prisms and pyramids, students are required to identify the elements of solid figures, calculate surface area and volume, and apply these concepts to solve real-life problems.

Concept analysis: This step involved identifying and organising the key mathematical concepts relevant to the topic. It revealed strong connections between the study of three-dimensional shapes and local cultural artefacts. Traditional objects, such as *ketupat*, *patlau*, and *pengkang*, possess geometric structures similar to those of prisms and pyramids. These findings served as the foundation for integrating ethnomathematics elements into the learning media. *Specification of Learning Objectives*, based on the previous analyses, the learning objectives were established to ensure that students can (1) understand the concepts of prisms and pyramids contextually, (2) relate mathematical ideas to local cultural elements, and (3) apply this knowledge to solve mathematical problems in daily life.

Design stage

The *Design* stage aims to plan and design the interactive learning media and research instruments to be used during the development process. Based on the needs analysis from the *Define* stage, this phase includes three primary activities: *developing tests and research instruments*, *selecting media and format*, and *initial product design*. Developing tests and research instruments can be seen in detail in [Tables 1 to 3](#).

Selection of media and format: The learning media were developed using the SAC application. This platform was chosen because it supports integrating text, images, videos, animations, and interactive quizzes into a single application that runs offline on Android devices. SAC was also selected for its user-friendly interface, flexible design capabilities, and attractive visual presentation, which can enhance students' learning motivation. Android-based media were considered appropriate since most students already have access to smartphones. The use of mobile technology helps teachers create more modern, interactive, and student-centred learning environments. With its multimedia format, the media accommodate diverse learning styles—visual, auditory, and kinesthetic—while fostering students' active engagement in the mathematics learning process.



Figure 3. Learning Material Display

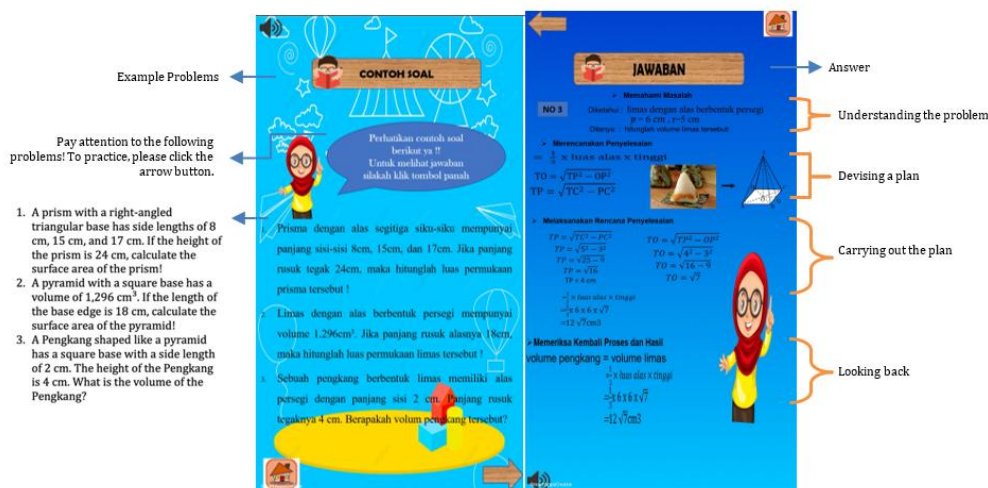


Figure 4. Exercise Display

Initial product design: An interactive Android-based learning media that integrates ethnomathematical content on prisms and pyramids. The media were designed to help students understand spatial concepts visually. The *main menu* serves as the navigation hub, connecting users to all sections of the media. It consists of five interactive icons: User Guide, Learning Objectives, Material, Exercises, and Evaluation, which can be seen in Figure 2. The dominant use of soft blue and orange colours creates a cheerful, engaging interface. At the same time, each icon includes simple animations that make navigation more intuitive and appealing for both teachers and students.

The learning material section presents the concepts of prisms and pyramids through text, images, and three-dimensional animations, as shown in Figure 3. This section also includes examples of traditional objects, such as ketupat and pengkang, which are traditional foods from West Kalimantan that resemble prisms and pyramids. The integration of ethnomathematical elements through these traditional foods connects mathematical concepts with local culture, helping students realise that mathematics exists in and relates to their everyday lives. Figure 3 shows 3D visualisations of prisms and pyramids along with images of ketupat and pengkang as ethnomathematical examples. "Next" and "Back" navigation buttons allow users to move between pages.

The exercise and evaluation section provides contextual, ethnomathematics-based questions that students can complete directly on their devices, as can be seen in Figure 4. This feedback system not only informs students whether their answers are correct but also helps them understand the reasoning process behind each solution. This page contains sample questions consisting of three

Table 4

Results of material expert validation		
Validator	Percentage (%)	Category
Validator 1	98.10	Very Valid
Validator 2	84.00	Very Valid
Validator 3	98.10	Very Valid
Average	93.40	Very Valid

Table 5

Results of media expert validation		
Validator	Percentage (%)	Category
Validator 1	96.47	Very Valid
Validator 2	97.65	Very Valid
Validator 3	97.65	Very Valid
Average	97.25	Very Valid

Table 6

Recapitulation of media and material validation results		
Type of Validator	Average (%)	Category
Material experts	93.40	Very Valid
Media experts	97.25	Very Valid
Overall Average	95.33	Very Valid

Table 7

Results of media the practicality test of the learning media		
Respondent	Average (%)	Category
Teachers	95.00	Very Practical
Students	92.89	Very Practical
Overall Average	93.95	Very Practical

essay questions and answers. Consistent with the rest of the media, this page adopts a predominantly blue and yellow colour scheme to maintain visual coherence and reflect the theme of natural beauty.

Overall, the initial product design produced an interactive, contextually relevant, and user-friendly learning medium. The integration of local cultural elements, particularly traditional foods such as *ketupat* and *pengkang*, is expected to increase students' learning motivation, enhance their conceptual understanding of three-dimensional geometry, and foster an appreciation for local culture through meaningful mathematics learning.

Develop stage

The *development* stage aimed to examine the validity, practicality, and effectiveness of the Android-based interactive learning media integrated with ethnomathematics on the topic of prisms and pyramids. This stage included expert validation, practicality testing by teachers and students, and effectiveness testing on students' mathematical problem-solving skills.

Expert validation results

The validation process involved three material experts and three media experts. It was conducted to ensure that the learning media met the requirements for content accuracy, linguistic clarity, and visual design before implementation. The assessments were rated on a 1–5 scale, converted into percentages, and categorised as very valid if the score reached at least 81%.

Material expert validation

Material validation covered aspects such as the suitability of the content with the learning objectives, conceptual accuracy, integration of ethnomathematics, and language clarity. As shown in Table 4, the material validation achieved an average of 93.40%, indicating a high level of validity, confirming that the media content aligns well with the curriculum, learning objectives, and the integration of ethnomathematical contexts. Feedback from validators was used to refine the media, particularly regarding the interactive quiz section. One correction involved revising the answer key for a question on the volume of a prism (from option C to B). After revision, the media was declared valid and ready for use without further modification.

Media expert validation

Media validation assessed linguistic aspects, visual quality, navigational ease, and the appropriateness of the design for students. The validation results from the three experts are shown in Table 5. Based on Table 5, the average score from media experts was 97.25%, categorised as very valid. The experts noted that the media had an attractive design, easy navigation, and colour combinations suitable for junior high school students. Suggestions for improvement included enlarging the font size on the practice pages and adding a *home* button on each page to simplify navigation. These recommendations were implemented in the final version of the product. As seen in Table 6, the overall average validation score was 95.33%, categorised as very valid. This confirms that the Android-based interactive learning media integrated with ethnomathematics met the

validity criteria for content, language, and visual presentation and was ready to be tested for practicality.

Table 8
T-Test: Paired two-sample for means

	<i>Posttest</i>	<i>Pretest</i>
Mean	90,83	51,11
Variance	68,67	260,97
Observations	10	10
Pearson Correlation	0,83	
Hypothesized Mean Difference	0	
df	9	
t Stat	12,17787190	
P(T<=t) one-tail	0,00000034	
t Critical one-tail	1,83311293	
P(T<=t) two-tail	0,00000068	
t Critical two-tail	2,26215716	

Practicality test results

The practicality test aimed to determine the ease of use of the media by teachers and students. Data were obtained from teacher and student response questionnaires after limited trials at the partner school. As shown in Table 7, the overall average score was 93.95%, indicating it is very practical. Teachers reported that the media were easy to use and supported independent learning, while

students found it engaging, interactive, and contextually relevant because it incorporated local cultural elements. According to established criteria, learning media are considered practical if the average score is at least 81% and users (teachers and students) can operate them without significant difficulty. Therefore, the developed media can be classified as very practical and suitable for further effectiveness testing.

Effectiveness test results

The effectiveness test examined the impact of the media on students' mathematical problem-solving skills. The pretest and posttest data were analysed for normality and then using paired t-tests. The results of the pretest normality test for students' problem-solving skill showed that $L_{count} = 0.227$ and $L_{table} = 0.258$ (at significance level $\alpha = 0.05$), indicating that $L_{count} < L_{table}$. Thus, the pretest data are normally distributed. Furthermore, the results of the posttest normality test indicate that $L_{count} = 0.134$ and $L_{table} = 0.258$ (at significance level $\alpha = 0.05$), so that $L_{count} < L_{table}$. Thus, the posttest data are normally distributed. The paired t-test results are shown in Table 8.

Based on the results of the paired t-test in Table 8, the calculated t-value was 12.18 with a p-value of 0.00000034, which is smaller than the significance level of 0.05. This indicates a significant difference between the pretest and posttest scores. The average posttest (90.83) is higher than the average pretest (51.11), indicating that the provided m-learning has a positive, significant effect on students' mathematical problem-solving skills. Furthermore, based on Table 8, the Cohen's effect size obtained is $d = \frac{M_1 - M_2}{SD_{pooled}} = \frac{90.83 - 51.11}{\sqrt{\frac{68.67 + 260.97}{2}}} = \frac{39.72}{12.84} = 3.09$. Cohen's effect size value of 3.09 indicates that

the difference between the pretest and posttest scores falls into the huge category. With a value of $d = 3.09$, the effect produced by the use of m-learning in this study can be considered very strong.

The effectiveness of this study was also assessed using posttest results, which were analysed using descriptive statistics. This was achieved by interpreting the results, which involved dividing the number of students who completed the course by the total number of students and then expressing the result as a percentage. The completion rate of the students' posttest results was based on the Minimum Completion Criteria for Mathematics subjects, which was 80%. Based on the study's results, the posttest calculation yielded a 90% value, meeting the very effective criteria. Thus, M-Learning media incorporating ethnomathematics can be used to enhance students' mathematical problem-solving skills.

After the media was implemented, users provided several suggestions. User experience during implementation also revealed challenges due to limited instructional time. The teacher noted that the classroom learning time was insufficient to fully explore all the interactive features of the media, especially the 3D animations and ethnomathematics-based exercises, which required more time for students to understand. In addition, the teacher suggested that the media should not only feature cultural examples in the form of Pontianak's traditional foods but also include other cultural elements to broaden ethnomathematics coverage and enrich students' learning context.

Disseminate Stage

The *Disseminate* stage is the final phase of the 4D development model, aimed at distributing the learning media that have been declared valid, practical, and effective, so a broader range of users can utilise them. In this study, dissemination activities were conducted on a limited scale due to time constraints and the research's scope. *Packaging (product refinement)* was conducted after the learning media were deemed feasible based on expert validation, practicality tests, and effectiveness tests. This stage aimed to refine the final revisions to ensure that the media were ready for classroom use. The improvements included adjusting the font size to be proportional on mobile screens, adding a *home* button on each page to facilitate navigation, and refining the layout to make the media's appearance more attractive and consistent. After refinement, the media were packaged in the form of an APK (Android Application Package) file named "Ethnomathematics-Based Learning Media on Prisms and Pyramids." The final product was designed to be installed and run on various Android devices with an efficient file size, making it easily accessible and usable by both teachers and students.

Diffusion and adoption were conducted after the final product was completed and declared suitable for use. At this stage, the learning media were disseminated at school where the limited trial was conducted. The activities included handing over the final product to mathematics teachers as an APK file, accompanied by an explanation of the installation process, main features, and ways to integrate it into classroom learning activities. Additionally, a direct demonstration of the media's use was conducted for both teachers and students, along with initial mentoring to help teachers integrate the media into their lesson plans.

DISCUSSION

The results of the study show that the Android-based interactive learning media integrated with ethnomathematics developed in this research demonstrate very high validity, practicality, and effectiveness, making it feasible for use in mathematics learning at the junior high school level. Based on validation by three expert validators, the overall average validity score was 95.33%, placing it in the very valid category. The material aspect achieved an average of 93.40%, while the media aspect reached 97.25%. These results indicate that the media meet the criteria for content accuracy, communicative language, and an appealing and easy-to-understand design. Such a high level of validity ensures that the media aligns well with students' characteristics and learning objectives, making it an effective tool for improving students' conceptual understanding. This finding is consistent with Nasution and Lailia (2023), Andang et al. (2025), and Dwijayani (2019), who stated that well-validated educational media significantly contribute to the success of mathematics learning, particularly in enhancing conceptual understanding and problem-solving skills. Similarly, Emphasised that strong expert validation of digital learning media has a direct positive impact on student engagement and learning outcomes (Liliana et al., 2020; Sappaile et al., 2023).

In addition to validity, the media also demonstrated high practicality. Based on teacher and student response questionnaires, the average score was 93.95%, categorised as very practical. Teachers found the media easy to use, efficient in supporting learning activities, and effective in transforming abstract material into more concrete, context-specific forms. Students also reported that the media was engaging, easy to understand, and capable of fostering their interest in learning. This high level of practicality indicates that the media is not only valid in terms of content but also effective in real classroom implementation. This finding is supported by previous research showing that ease of use of digital learning media directly contributes to increased student motivation and understanding of mathematical concepts (Dewi et al., 2024; Rachmavita, 2020). Android-based

interactive learning media can improve students' mathematical problem-solving skills (Yani et al., 2021).

The *effectiveness test* results revealed a significant improvement in students' mathematical problem-solving skills. Based on the *paired t-test* results, there was a statistically significant difference between the average pretest score (51.11) and posttest score (90.83), with a $p\text{-value} = 0.00000034 < 0.05$. This improvement indicates that the Android-based interactive learning media had a significant positive impact on students' skills to understand and solve mathematical problems. The interactive features encouraged students to actively explore concepts through simulations, exercises, and quizzes that provided immediate feedback. This result aligns with the idea that technology-based interactive learning enhances higher-order thinking skills, including problem-solving (Alghamdi, 2025; Cheng et al., 2023; Setyaningrum et al., 2024).

The huge effect size obtained in this study (Cohen's $d = 3.09$) warrants critical examination. Several meta-analyses have confirmed that ethnomathematics-based learning generally exerts a significant influence on students' mathematical problem-solving skills (Wirawan et al., 2024), on geometry learning at the junior high school level (Istia et al., 2025), and on mathematics achievement more broadly (Sulistiyowati, 2024). Nevertheless, the magnitude of effects reported across studies varies depending on the type of media employed, the research design, sample characteristics, and the cultural context integrated into the learning process. The exceptionally high value obtained in the present study may be attributable to several distinctive features of the developed media. First, the in-app quiz system provided immediate corrective feedback, enabling students to identify and rectify misconceptions in real time rather than allowing errors to persist across sessions. Second, the three-dimensional animations of local cultural artefacts—ketupat, patlau, and pengkang—offered dynamic spatial representations of prisms and pyramids that static media cannot replicate. Third, the application's offline-accessible format allowed students to revisit instructional content independently outside formal classroom hours. Nevertheless, these results must be interpreted with caution, given that the study involved only 10 students in a small-scale pilot trial without a comparison group, so the very large effect size cannot yet be generalised. Future research employing larger samples and controlled experimental designs is therefore necessary to verify the consistency of these findings.

The success of this learning media is also closely linked to the crucial role of ethnomathematics in bridging abstract mathematical concepts with students' real-life contexts. Mathematics is inherently abstract—concepts such as geometric solids, volume, and surface area are often difficult for students to grasp because they are detached from direct experience. Therefore, an approach that connects these abstract concepts to daily life is necessary. Ethnomathematics serves as a bridge linking cultural knowledge with formal mathematical concepts, helping students uncover the meaning behind symbols and formulas through contexts familiar to them. In the developed media, local cultural objects such as *ketupat* and *pengkang* were used as tangible representations of geometric shapes, allowing students to identify components like faces, edges, and vertices concretely. This finding aligns with previous research suggesting that integrating local cultural contexts into mathematics learning strengthens conceptual understanding and increases student motivation (Khasanah et al., 2025; Leton et al., 2025). The embedding of ethnomathematics within digital media enhances the meaningfulness of learning by connecting students' cultural experiences to formal mathematical structures (Supriyadi et al., 2024; Wulandari et al., 2024). Similarly, Fouze and Amit (2017) and Sari et al. (2023) emphasised that because mathematics is abstract, a "cultural bridge" is essential to help students internalise these concepts through cultural experiences, and the ethnomathematical approach has proven effective in bridging this gap.

Beyond the cultural bridge, improvements in students' problem-solving skills can also be explained by the structural alignment between the media's design and Polya's problem-solving framework. Each exercise and evaluation item within the application was explicitly constructed to guide students through four problem-solving stages: understanding the problem, devising a solution plan, executing the plan, and reviewing the result. Rather than presenting problems without guidance, the media scaffolded each stage visually, prompting students to record known information, select appropriate formulas, and verify their calculations before proceeding to the next step. This

step-by-step approach has been shown to reduce students' cognitive load, particularly for those who previously struggled to determine an initial course of action when confronted with unfamiliar problem structures. Furthermore, the contextualisation of problems using culturally familiar objects—such as calculating the surface area of a *ketupat* or the volume of a *pengkang*-shaped container—has been shown to enhance students' mathematical thinking and engagement with abstract concepts (Fouze & Amit, 2018), while the use of culturally contextualised problems has been demonstrated to strengthen students' problem-solving abilities (Alghiffari et al., 2024). The convergence of structured scaffolding, cultural contextualisation, and interactive feedback thus collectively accounts for the substantial gains observed between the pretest and posttest.

Overall, the improvement in students' problem-solving skills was due not only to the interactive, content-valid design of the media but also to the strength of the ethnomathematical approach, which connects formal mathematical knowledge with students' social and cultural realities. The integration of technological and cultural aspects created a meaningful, context-rich learning experience that fostered students' higher-order thinking skills. Previous studies have demonstrated that integrating technology with cultural contexts or local wisdom significantly enhances meaningful, contextually relevant learning experiences, encouraging the development of higher-order thinking skills (Hikmawati et al., 2024; Kwangmuang et al., 2021). This media provided students with opportunities to realise that mathematics is not merely a collection of abstract formulas but an integral part of their daily lives, reflected in the culture, objects, and traditions they encounter.

The findings from this study on integrating ethnomathematics into Android-based learning media to improve students' problem-solving skills are highly relevant to teaching practice and educational policy. The core relevance lies in demonstrating an effective, engaging, and culturally responsive model for mathematics education that leverages modern technology. For teachers, the study provides a practical, validated pedagogical model for contextualising learning. It offers teachers a framework for making abstract mathematical concepts, particularly in areas like geometry, concrete and meaningful by linking them to students' local culture and daily experiences (ethnomathematics), which is shown to increase student motivation and understanding. For educational policymakers and curriculum developers, the findings offer empirical evidence to support shifts toward more culturally inclusive and technologically advanced curricula. The study provides a strong rationale for the inclusion of local cultural contexts (ethnomathematics) in learning materials (formal mathematics curriculum), moving beyond a purely Eurocentric approach. Additionally, it supports policies that advocate for the development and widespread adoption of educational technology, specifically mobile-based media, to ensure learning resources are modern, interactive, and aligned with the demands of the digital age.

This study involved only 10 participants because it was a small-scale pilot trial. The very small sample size means the findings cannot yet be generalised broadly. Although the results indicate improvements in problem-solving skills and positive responses toward the media, further research with a larger, more diverse group of participants is needed to comprehensively evaluate the media's effectiveness. In addition, the feedback provided by users during this pilot phase—such as the need for more diverse cultural content and adjustments to the allotted time for using the media—serves as an important foundation for future development before the media is widely implemented in broader learning contexts.

Based on the results and limitations of this study, it is recommended that future research be conducted on a larger scale to examine the media's effectiveness across different schools and cultural contexts. Subsequent studies may employ experimental designs with control groups to compare the effects of ethnomathematics-based media with those of conventional learning media. Additionally, longitudinal studies could be conducted to assess the sustainability of students' problem-solving improvement over extended use of the media. Future developments could also enrich the content with other cultural objects beyond *ketupat* and *pengkang*, thereby expanding ethnomathematical representation and enhancing the media's cultural relevance across different regions.

CONCLUSIONS

This study successfully developed an interactive Android-based learning media integrated with ethnomathematics for teaching prisms and pyramids. The validation results indicated that the media is highly feasible in terms of content, presentation, and cultural relevance. The practicality test showed positive responses from teachers and students, suggesting that the media is easy to operate, engaging, and supportive of learning activities. Furthermore, the media's effectiveness was demonstrated by its ability to foster students' mathematical problem-solving skills, as reflected in a very large effect size. Theoretically, this study contributes to the development of technology-based and culturally integrated learning media. The integration of ethnomathematics shows that cultural contexts can help students connect abstract geometric concepts with real-life experiences, thereby deepening conceptual meaning and increasing engagement in learning. While promising, these findings are preliminary and confined to a specific cultural and institutional context, warranting further investigation before broader claims can be made.

These findings carry practical implications for multiple stakeholders. Teachers may adopt the developed media as a contextual and visually interactive resource for geometry instruction. Schools may draw on these results to support digital learning innovations that incorporate local cultural contexts. At the same time, policymakers may use the evidence to advocate for culturally inclusive, technology-enhanced mathematics curricula.

This study has several limitations that directly inform future research directions. The small sample size ($n = 10$) limits the generalizability of the findings, and the limited instructional time prevents a full exploration of the media's features. Furthermore, the cultural content focused solely on Pontianak's traditional foods, and no longitudinal assessment of concept retention or sustained problem-solving development was conducted. Future research should therefore employ larger, more diverse samples, extend the implementation period, broaden the cultural repertoire beyond local culinary artefacts, and adopt experimental designs with control groups to establish more robust causal evidence. Longitudinal studies are also encouraged to evaluate the sustained impact of the media on students' mathematical problem-solving competencies over time.

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AUTHOR'S DECLARATIONS

Authors' contributions

HH: Conceptualisation, Writing - Original Draft, Methodology, Investigation and Visualisation; PK: Writing - Review & Editing; Formal analysis; Resources, and Validation. GS: Writing - Review & Editing, Validation, Formal analysis, and Methodology; VA: Visualisation and Software; HH: Formal analysis, Investigation, Resources, and Data Curation;.

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Competing interests

The authors declare no conflict of interest.

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