



From Lampung Culture to Geometric Understanding: A Digital Ethnogeometry Framework with Augmented Reality

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Abstract

Geometry still becomes difficult for students when spatial relationships are taught mainly through procedures and fixed images that have little connection with the daily environment. This study develops and validates the Digital Ethnogeometry Model (EGL-Model) at the expert level. The model combines Lampung ethnomathematics, Van Hiele theory of geometric thinking, CTML, and AR. Design-Based Research approach is applied, but the work only covers the early design cycle. Activities include desk-based preliminary inquiry, development of a conceptual framework, creation of an offline Unity 3D AR proof of concept, evaluation by experts from different fields, together with design revision. *Menara Siger*, *Lamban Dalom*, and *Lampung Tapis* connect with junior-secondary geometry topics. These cultural objects are placed within five learning stages: cultural artifact exploration, geometric identification, formal concept connection, cultural value reflection, together with mathematical problem solving. Five experts assessed the model in terms of pedagogical coherence, cultural authenticity, and technological functionality. The corrected overall mean reached 4.21/5.00, which passes the predetermined criterion for a highly valid design. Cultural authenticity had the highest mean at 4.27, followed by technological functionality at 4.19 and pedagogical coherence at 4.18. Expert comments mainly ask for a clearer connection between learning stages, stronger cultural explanation, and a clearer interface. Findings indicate that experts consider EGL-Model content and design valid as a proof of concept. However, the results do not confirm teacher or student usability, classroom practicality, or learning effectiveness. These aspects need to be examined within a later field-based DBR cycle.

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INTRODUCTION

Understanding geometry is important because students need to work with visual, spatial, and relational information, not only remember formulas. Many students still have problems with spatial visualization and geometric reasoning, especially when they need to change from concrete or visual form toward abstract relationships (Muhammad et al., 2026; Muhassanah et al., 2025; Parandreni, 2024; Vásquez Hidalgo et al., 2025). Within Lampung, Marian et al. (2025) find that more than 60% of junior high school students remain below the minimum competency threshold in three-dimensional geometry and geometric transformation. This problem can become greater when

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classroom instruction focuses heavily on procedures, formula memorization, and fixed two-dimensional pictures. Such an approach gives students limited help in building and changing mental images of three-dimensional objects (Gilligan-Lee et al., 2022; Kim, 2020; Rossano et al., 2020). Therefore, the main issue is not only the geometry of the material itself. Students also need learning experiences that connect meaningful representation with increasingly formal ways of geometric reasoning.

Ethnomathematics can help build this connection because familiar cultural practices and objects can be used to explain mathematical ideas, rather than only being used as decoration (Atmaja et al., 2025; Rosa & Shirley, 2016). Lampung cultural objects, including *Menara Siger*, *Lamban Dalom*, and Tapis motifs, show forms that can relate to solid geometry, plane figures, symmetry, proportion, and geometric transformations. Earlier studies within Lampung have already identified these mathematical elements (Efendi et al., 2025; Marian & Saputra, 2023; Susiana et al., 2020). However, these studies mainly describe and document mathematics found within cultural objects. They do not clearly provide a theory-based learning path that takes students from seeing cultural forms toward examining their properties, connecting them with formal geometry, and finally using concepts to solve problems. Thus, cultural material already exists, but a clear instructional process for turning it into structured geometry learning remains limited.

AR can help address this problem because it changes cultural objects from fixed pictures into representations that students can interact with. The integration of digital technology into learning also requires an organized learning environment in which digital tools are incorporated into planning, implementation, and evaluation of instruction (Hafid & Barnoto, 2022). Within geometry learning, students can use AR to rotate, inspect, compare, and break down three-dimensional objects. These actions can help them visualize objects and connect different forms of representation (Cetintav & Yilmaz, 2023; Flores-Bascuñana et al., 2020; Rossano et al., 2020). Previous AR and ethnomathematics studies also indicate that local culture can combine with digital visualization (Gustina et al., 2025; Umri et al., 2025). Even so, existing studies do not yet form a clear and complete direction. Some focus on media validity, student motivation, or visualization without explaining how geometric reasoning should develop. Others use common geometric objects instead of meaningful cultural objects. Many digital learning systems also depend on stable internet access, which may become difficult for schools with limited infrastructure (Abdullah et al., 2022; Firdausi, 2025; Mkwizu & Bordoloi, 2024). AR can improve representation, but it does not, by itself, explain how students should move from observing objects toward understanding their geometric relationships.

The design problem can be explained through four related gaps. First, many cultural geometry resources have already been identified, but they are not always converted into organized learning activities. Second, the learning steps from visual recognition toward analysis and informal deduction are often not clearly stated. Third, AR features are seldom connected directly with the stages of geometric thinking proposed by Van Hiele. Fourth, the possibility of using AR without continuous internet access receives little attention, even though connectivity can become a real problem in many non-urban schools. These gaps cannot be solved simply by putting several existing approaches together. A clearer design structure needs to be developed so every component has its own role while still working together within one learning process.

The EGL model was created to provide this structure. Ethnomathematics is used to select cultural objects and meanings that become the starting point of learning. Van Hiele theory provides the expected movement from visualization toward analysis and informal deduction. CTML helps organize visual, verbal, symbolic, and interactive information. AR can then be used as a medium through which students interact with cultural and geometric representations. Such integration is consistent with the broader need to integrate educational technology into instructional practice while strengthening educators' capacity to use digital platforms meaningfully (Hakim & Abidin, 2024). These elements connect through five stages: cultural artifact exploration, geometric identification, formal concept connection, cultural value reflection, and mathematical problem solving. The main contribution refers to a clear design pathway that connects cultural artifacts, geometric ideas, reasoning development, multimedia information, and digital interaction. AR is therefore treated as part of learning design, not as the main purpose of the application.

This study has four main objectives. The first objective was to develop a conceptual framework and a five-stage learning sequence of the EGL-Model. The second was to create an offline Unity 3D-

based AR proof of concept using a selected Lampung cultural artifact. The third was to assess expert perception regarding pedagogical coherence, cultural authenticity, and technological functionality. Fourth was revising the framework and prototype based on numerical ratings and written expert comments. The study only covers preliminary inquiry, design and construction, expert evaluation, and revision. It does not examine teacher or student usability, classroom practicality, or learning outcomes. With this limited scope, the study provides an expert-validated design proposition that may serve as a basis for a later DBR cycle. A future cycle can involve direct user testing, classroom implementation, and evaluation of instructional effectiveness.

METHOD

This study used a Design-Based Research (DBR) approach because DBR supports the iterative alignment of theoretical learning principles, contextual educational problems, and instructional design (Akindede, 2025; Asrifan et al., 2025; Barab, 2022; Cochrane et al., 2024; Flynn et al., 2022; Mygdanis, 2025). The procedure followed the educational design research framework of (McKenney & Reeves, 2019) which involves analysis and exploration, design and construction, and evaluation and reflection. In the present study, the preliminary inquiry was desk-based and consisted of reviewing documented difficulties in geometry learning, published Lampung ethnomathematics and cultural sources, and technological and instructional constraints associated with geometry visualization. No separate stakeholder interviews, classroom observations, or field-based needs assessment were undertaken at this stage. Findings from this preliminary inquiry informed the initial conceptual framework. The development procedure below translated this DBR logic into four operational phases: conceptual formulation and artifact-to-concept mapping, AR prototype construction, multidisciplinary expert validation, and evidence-based revision. These activities represent an early DBR design cycle rather than a complete DBR implementation; classroom enactment, user-based usability testing, and empirical effectiveness evaluation were reserved for subsequent cycles.

Development Procedure

The EGL-Model and AR proof of concept were developed through four operational phases. Figure 1 shows the iterative relationship among conceptual formulation, prototype construction, expert evaluation, and revision:

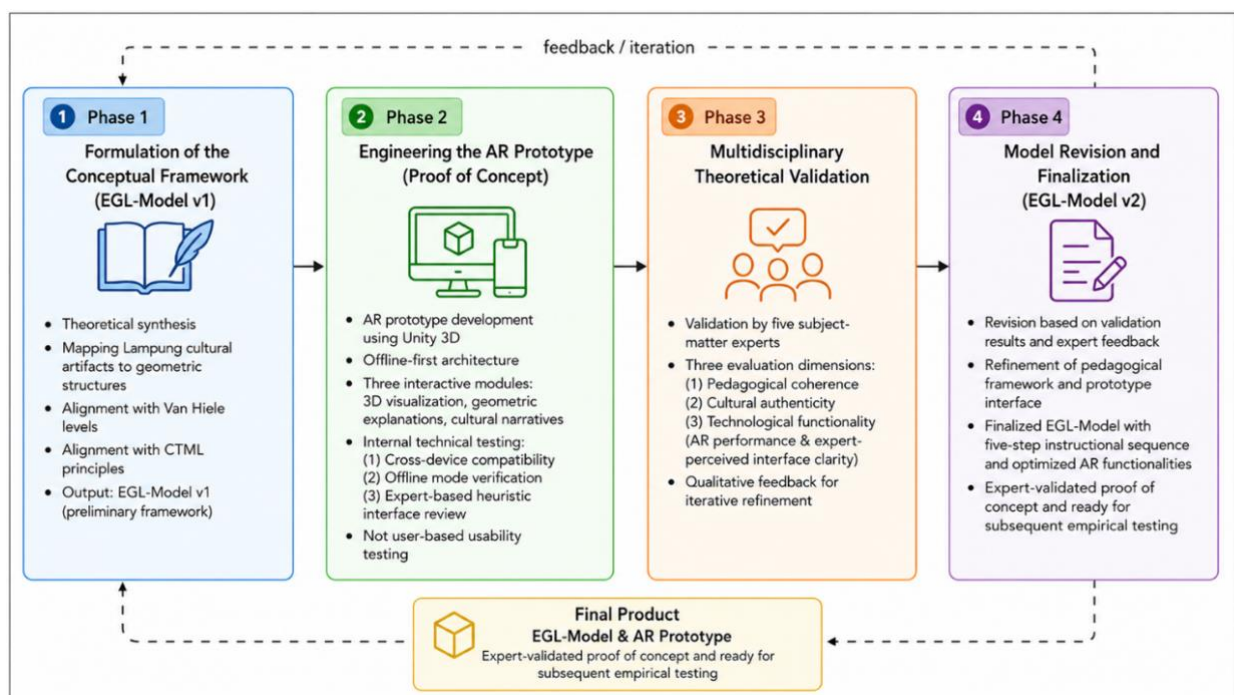


Figure 1. Research Procedure Flowchart

Phase 1: Formulation of the Conceptual Framework (EGL-Model v1)

Phase 1 used a structured artifact-to-concept analysis. First, *Menara Siger*, *Lamban Dalom*, and *Lampung Tapis* were selected because they are repeatedly documented in Lampung-focused ethnomathematics studies and contain geometric forms relevant to junior-secondary learning (Efendi et al., 2025; Lestari et al., 2025; Loviana et al., 2020; Marian & Saputra, 2023; Noprisa et al., 2024; Susiana et al., 2020). Second, we identified visible structural units in each artifact, such as roof and tower profiles, architectural parts, and repeated textile motifs. Third, the authors classified these units using formal geometric properties, including solid figures, plane figures, symmetry, proportion, tessellation, and rigid or non-rigid transformations. Fourth, the resulting concepts were aligned with the junior-secondary geometry topics shown in Table 1. Fifth, the learning actions were mapped to Van Hiele's progression and CTML principles: visual exploration supported initial recognition; property-focused prompts supported analysis; comparison, justification, and formalization supported movement toward informal deduction; and CTML principles guided the placement of labels, short explanations, formulas, and visual cues. The study synthesized cultural narratives from the Lampung-focused sources used and then examined them within the cultural-authenticity dimension with a Lampung cultural-studies expert. The study did not claim to produce new ethnographic findings from these narratives.

Phase 2: Engineering the AR Prototype (Proof of Concept)

The AR proof-of-concept was built from EGL-Model v1 using Unity 6000.4.3f1 for Android devices. Image recognition is handled by the Vuforia Engine. When the image target is detected, the related three-dimensional cultural artifact appears. Three-dimensional assets are prepared and optimized in Blender before importing into Unity. In Unity, the model is combined with geometric labels, formulas, short explanations, and cultural narratives. Application design for Android 7.1 Nougat (API Level 25) and later. Technical testing uses a minimum device profile of 2 GB RAM, a quad-core 1.3 GHz processor, a rear camera of at least 5 MP, and a GPU with OpenGL ES 3.0 support. Image targets, 3D models, interface components, labels, formulas, and learning content are all stored locally within the application. Therefore, the main learning function can work without continuous internet access after installation. Before expert validation, we conduct internal checks for image-target recognition, local asset loading, offline use, screen navigation, and frame stability on devices that meet minimum specifications. These checks represent only technical engineering validation for proof-of-concept feasibility. They are not usability tests involving teachers or students, nor performance tests using a representative range of devices.

Phase 3: Multidisciplinary Theoretical Validation

Five subject-matter experts assess EGL-Model v1 and its AR proof of concept. Each expert completes a 27-item instrument covering pedagogical coherence, cultural authenticity, and technological functionality. They also provide written comments on the design's strengths, problems, and possible improvements. Numerical data are summarized for each validator and each domain. Group written responses by the design issue they address. This validation stage is formative in nature. Scores show which areas are relatively stronger or weaker, while comments help explain the reasons behind the ratings and the parts that need improvement.

Phase 4: Model Revision and Finalization (EGL-Model v2)

Within Phase 4, validation evidence is used to decide revisions. First, compare quantitative scores to identify stronger and weaker domains. Next, organize qualitative comments into pedagogical, cultural, and technological issues. Each issue then connects to specific design changes. For the pedagogical side, clarify the purpose and links between the five stages. For the cultural side, cultural meaning and value play a stronger role during exploration and reflection. For the technological side, navigation and label presentation improve, while the offline local-asset system is kept. Written comments do not alter numerical scores. Instead, they help explain the score and guide the revision process. Revised EGL-Model v2 remains a proof of concept and still requires user and classroom testing.

Validation Instrument and Content Validity Procedure

The validation tool uses a 5-point Likert scale questionnaire with 27 items. Before use, an expert panel conducted a systematic content validity process. Items were developed from key indicators within the established Design-Based Research framework, including McKenney & Reeves (2019), and the main principles of multimedia learning theory proposed by Mayer (2009). Two independent experts reviewed the draft instrument for research methodology. They checked whether items were clear, indicators were relevant, and items matched the intended construct. Items that were unclear or conceptually weak were revised several times until experts reached agreement. The final instrument contains three domains: pedagogical coherence (10 items), cultural authenticity (9 items), and technological functionality (8 items). Validity criteria were decided before expert scoring. A mean of 3.75 out of 5 is set as the minimum score for validity, equivalent to 75% of the maximum score. This criterion serves as the decision rule for judging whether each domain has an acceptable level of expert agreement. A score below 3.75 means major revision is needed, while a score of 3.75 or above means the component meets the predetermined criterion. The same rule applies to pedagogical coherence, cultural authenticity, technological functionality, and the overall score (Mumu et al., 2022; Juliani & Erita, 2023).

Expert Selection Criteria

The expert panel was chosen purposively because the study needed different forms of expertise rather than statistical representation. Selection focused on relevant professional knowledge instead of academic rank alone. Academic validators (V1-V3 and V5) were selected based on disciplinary background, academic position, scholarly or research experience, and at least five years of experience in the related field. V4, the cultural validator, was selected for sustained professional involvement with Lampung cultural heritage and at least five years of related cultural practice. The panel consists of four academic experts and one cultural practitioner. Their field include mathematics education, ethnomathematics, curriculum design, Lampung cultural studies, and augmented reality or educational technology. This combination is intended to ensure that the pedagogical, cultural, curricular, and technological aspects of the model are reviewed by people with suitable expertise. Throughout the manuscript, five validators are identified as V1-V5 (see Table 1).

Table 1. Characteristics and Roles of the Expert Validators

Validator	Primary Expertise	Academic / Professional Position	Relevant Experience	Primary Validation Role
V1	Mathematics education	Associate Professor	9 years	Pedagogical coherence and geometry-learning logic
V2	Ethnomathematics	Lecturer	5 years	Cultural-mathematical integration
V3	Curriculum design	Lecturer	5 years	Instructional sequence and curriculum alignment
V4	Lampung cultural studies	Lampung cultural practitioner	6 years	Cultural authenticity and philosophical meaning
V5	AR / educational technology	Lecturer	7 years	AR functionality, interface clarity, and offline access

Five validators are chosen through purposive sampling. Several specific requirements are used so the panel can provide broad methodological triangulation.

- 1 Academic Competence: Academic validators must hold a doctoral degree (Ph.D. or equivalent) or an academic rank of Associate Professor or higher. They also need a clear publication record in the relevant academic field.
- 2 Domain-Specific Expertise: Each validator has specific knowledge related to one or more areas assessed in the validation process. These areas include mathematics education,

ethnomathematics, curriculum design, Lampung cultural studies, and augmented reality technology.

- 3 Practical Experience: Each expert has at least five years of direct experience in instructional media development or ethnomathematical research. This experience is needed so the evaluation can consider actual practice and local context.
- 4 Commitment to Iterative Engagement: Validators are willing to take part in several feedback stages. They also expect to provide detailed qualitative comments that can be used to improve the model.

The expert panel was intentionally formed with different areas of expertise. This composition allows the EGL model to receive an initial, broad review from pedagogical, cultural, and technological perspectives.

Data Analysis

Data from five expert validators were analyzed using descriptive statistics, mainly mean and standard deviation. Mean scores were calculated for each validation domain based on ratings from all five validators. The instrument covers three domains: pedagogical coherence (10 items), cultural authenticity (9 items), and technological functionality (8 items). After calculating the three domain scores, an overall composite mean was also obtained to describe the validity of the EGL-Model as a whole. Standard deviation is included to show how much expert ratings differ from one another. Inferential statistical tests were not used because validators were purposively selected and the expert panel included only five people.

Validity criteria were decided before data analysis began. A mean score of at least 3.75 on a five-point Likert scale is considered the minimum level for acceptable content and design validity (Mumu et al., 2022; Juliani & Erita, 2023). Expert written comments and recommendations are analyzed thematically to identify repeated issues related to pedagogy, culture, and technology (Mackiewicz, 2018). These comments are not used to change the numerical score. Instead, they help explain the scores and identify parts that need revision within EGL-Model v2. In this way, quantitative results show which areas are stronger or need more attention, while qualitative feedback explains these results and guides changes from Phase 3 toward Phase 4.

RESULTS AND DISCUSSION

EGL-Model: A Digital Ethnogeometry Framework

The main output of the study refers to the design structure presented in Figure 2. The figure does not place theory side by side as a separate part. Instead, each has a specific role within the same learning process. The Lampung cultural artifact becomes the material students explore. Van Hiele theory explains the expected development of geometric reasoning. CTML helps organize visual, verbal, symbolic, and interactive information. AR then allows students to interact with and manipulate representations of the artifact. These roles connect through five learning stages. Cultural artifact exploration mainly works at the visualization level because students first recognize form through familiar cultural objects. During geometric identification, students focus on properties and relationships, which relate to the analysis level within Van Hiele theory and are supported by CTML principles such as signaling and spatial contiguity. Formal concept connection asks students to compare properties, give formal names, and connect them with definitions and formulas. This stage supports movement from analysis toward informal deduction. Cultural value reflection does not represent a separate Van Hiele level. Instead, it keeps the cultural meaning of the artifact visible while students consider what mathematical representations can and cannot explain. Finally, mathematical problem solving asks students to apply and justify geometric relationships within contextual problems. The main importance of Figure 2 is that it highlights this connection between theory and stage. It explains how cultural context, geometric reasoning, multimedia presentation, and AR interaction are expected to work together (Alkharusi et al., 2019; Yuliardi & Rosjanuardi, 2021)

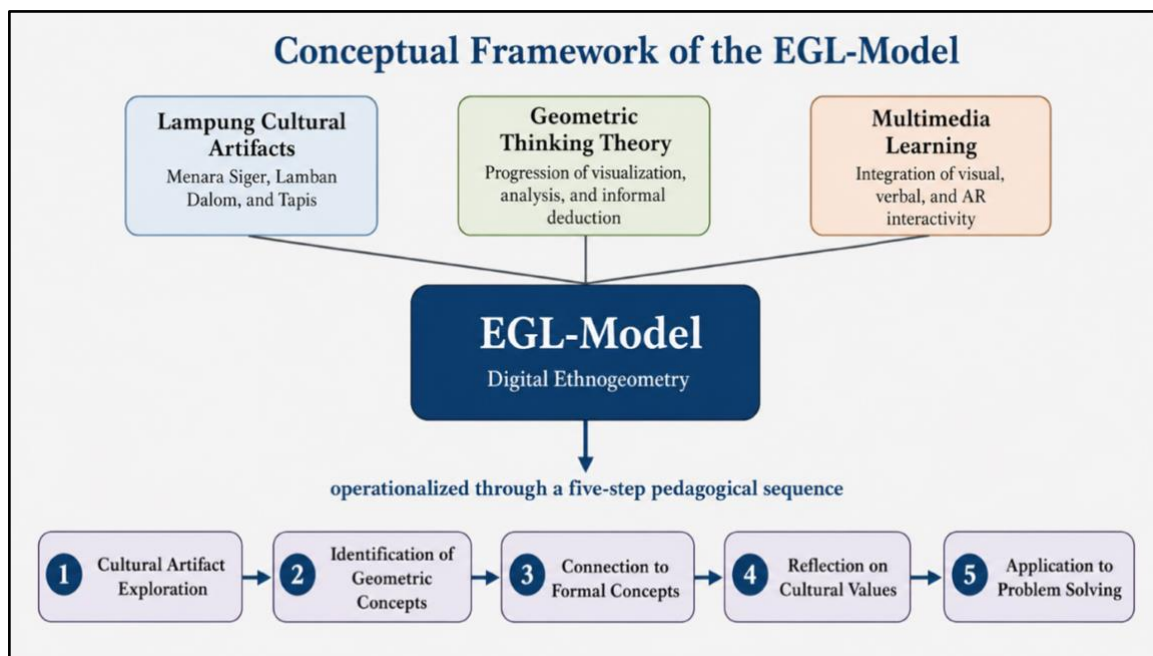


Figure 2. EGL-model: A digital Ethnogeometry Framework

Figure 2 also shows that the EGL model works as one connected learning system. The Lampung artifact becomes the first context for students to observe geometric features such as shape, symmetry, proportion, and transformation. These observations then develop through five learning stages, starting with cultural artifact exploration and geometric identification and continuing to formal concept connection, cultural value reflection, and mathematical problem solving. Van Hiele theory guides the development of geometric reasoning across these stages. At the same time, CTML organizes visual, verbal, and symbolic information so students can process relevant information more effectively. AR provides an interactive part of the system. Through AR, students can inspect, manipulate, and compare geometric properties found within cultural artifacts. Therefore, the learning process depends on the combined work of cultural context, geometric reasoning, learning sequence, multimedia representation, and digital interaction.

This structure also explains why AR is included in the EGL-Model. AR itself is not proof that learning has occurred. Its role is to provide representations that support the mental and visual activities required at each learning stage. The educational value of digital technology also depends on how it is planned, implemented, monitored, and evaluated within the learning process (Ulfah et al., 2026). For example, students can view an artifact from different angles, separate its geometric parts, and compare spatial relationships. Earlier studies on AR for geometry also report the usefulness of dynamic visualization for exploring spatial concepts (Flores-Bascuñana et al., 2020; Rossano et al., 2020). Within the EGL model, these AR functions connect with cultural tasks and the planned progression of geometric reasoning. Thus, AR helps students move from simply observing cultural objects to understanding their formal geometric meaning.

Mapping Lampung Cultural Artifacts to Geometric Concepts

Figure 3 presents three Lampung cultural artifacts that provide different but related ways to enter the school geometry curriculum. *Menara Siger* uses three-dimensional form, circles, symmetry, and proportional relationships. *Lamban Dalom* connects architectural form, quadrilaterals, prisms, symmetry, and similarity. Meanwhile, the Tapis motif shows repeated patterns that can be used to discuss translation, reflection, rotation, dilation, tessellation, and symmetry. This mapping not only shows that mathematical ideas can be found in local culture. More importantly, it shows that several geometry topics can be taught through a small group of recognizable local artifacts while keeping the cultural context connected. Artifacts can therefore be used as curriculum-related learning resources instead of being treated as separate cultural examples (Efendi et al., 2025; Lestari et al., 2025; Loviana et al., 2020).

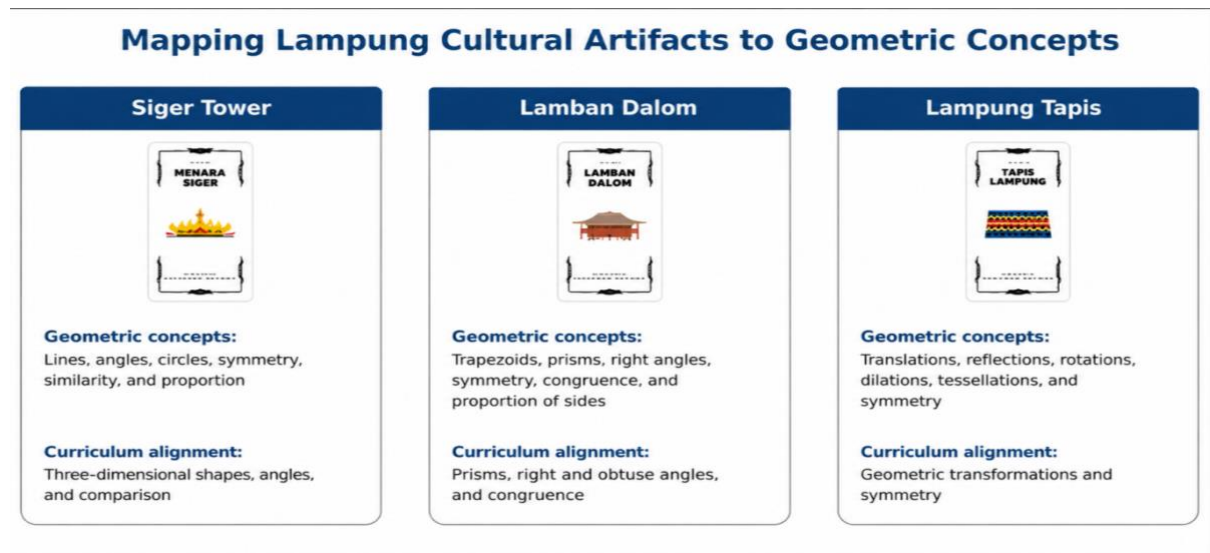


Figure 3. Mapping Lampung Cultural Artifacts to Geometric Concepts

Table 2 presents the detailed mapping between the identified geometric concepts and the junior-secondary school curriculum.

Table 2. Mapping geometric concepts embedded in Lampung cultural artifacts to the junior secondary school geometry curriculum

Cultural Artifact	Identified Geometric Concepts	Curriculum Alignment (Junior Secondary School)
<i>Menara siger</i>	Square pyramid, cone, circle, vertical line symmetry, proportional relationships	Grade VIII: three-dimensional geometry, surface area and volume of pyramids and cones; Grade VII: circles and ratios
<i>Lamban Dalom</i>	Trapezoids, triangular prisms, rhombuses, rectangular bases, bilateral symmetry, angular proportionality	Grade VIII: surface area and volume of prisms; Grade VII: quadrilaterals and triangles; Grade IX: similarity
<i>Lampung Tapis Motifs</i>	Translations, reflections, rotations, dilations, equilateral triangle tessellations, rotational and reflection symmetry	Grade IX: geometric transformations (translation, reflection, rotation, and dilation) and symmetry

Table 2 explains how artifact-to-concept mapping can be used in the curriculum. Mapping is not only for listing geometric forms found within Lampung culture. It can also be used to decide what students should observe, manipulate, compare, and later express through formal mathematical concepts. For example, learning with *Menara Siger* can start by asking students to observe its overall structure. They can then identify pyramid- and cone-like parts, compare their properties, and connect these observations to surface area and volume concepts. *Lamban Dalom* can help students move between plane and solid representations while exploring proportional and similarity relationships. Tapis motifs are especially useful for transformation activities because repeated patterns allow students to see translation, reflection, rotation, and dilation within one cultural object.

Mapping is therefore important for more than showing the presence of geometry within Lampung culture. It also explains how these geometric ideas can connect to curriculum content and become organized learning activities. Within the EGL-Model, geometric features identified from artifacts become the first material for planned reasoning processes and AR-based exploration. This approach transforms cultural artifacts from objects described only mathematically into resources for instructional design. Cultural context, curriculum goals, geometric reasoning, and digital interaction are intentionally connected. Earlier studies also discuss the educational value of digital and AR resources based on local culture. The EGL-Model adds a clearer connection between cultural artifacts, geometry concepts, and learning stages (Gustina et al., 2025; Marian & Saputra, 2023; Sapta et al., 2025).

AR Prototype as an Operational Representation of the EGL-Model

The prototype applies the EGL-Model through three learning modules based on selected artifacts and one shared navigation system. Each module contains a three-dimensional model for viewing. It combines cultural information, geometric parts, mathematical labels, and formulas, together with image-based AR visualization of the artifact. The design starts with a familiar cultural object and then directs students toward its geometric structure and meaning. Technical details of the Unity environment, image-recognition system, local asset structure, device specifications, and 3D asset development are explained within the Method section. This section instead focuses on how the interface turns the EGL-Model into a sequence of learning representations.

Figure 4 shows the main menu, artifact selection page, cultural information page, geometry page, and AR view for *Menara Siger* and *Lamban Dalom*, together with Lampung Tapis. The learning sequence starts with the cultural object and then moves toward its geometric part and formal mathematical representation. This order follows the EGL model's intended movement from cultural artifact exploration toward geometric identification and then formal concept connection. Students who have difficulty understanding three-dimensional geometry through formulas or fixed two-dimensional pictures can view the same object through several representations. This allows them to examine geometric form and spatial relationships while the object remains connected to a familiar cultural setting. However, these features only describe what the prototype provides. They should not be interpreted as evidence that the application improves learning outcomes. Such claims require further classroom-based evaluation.

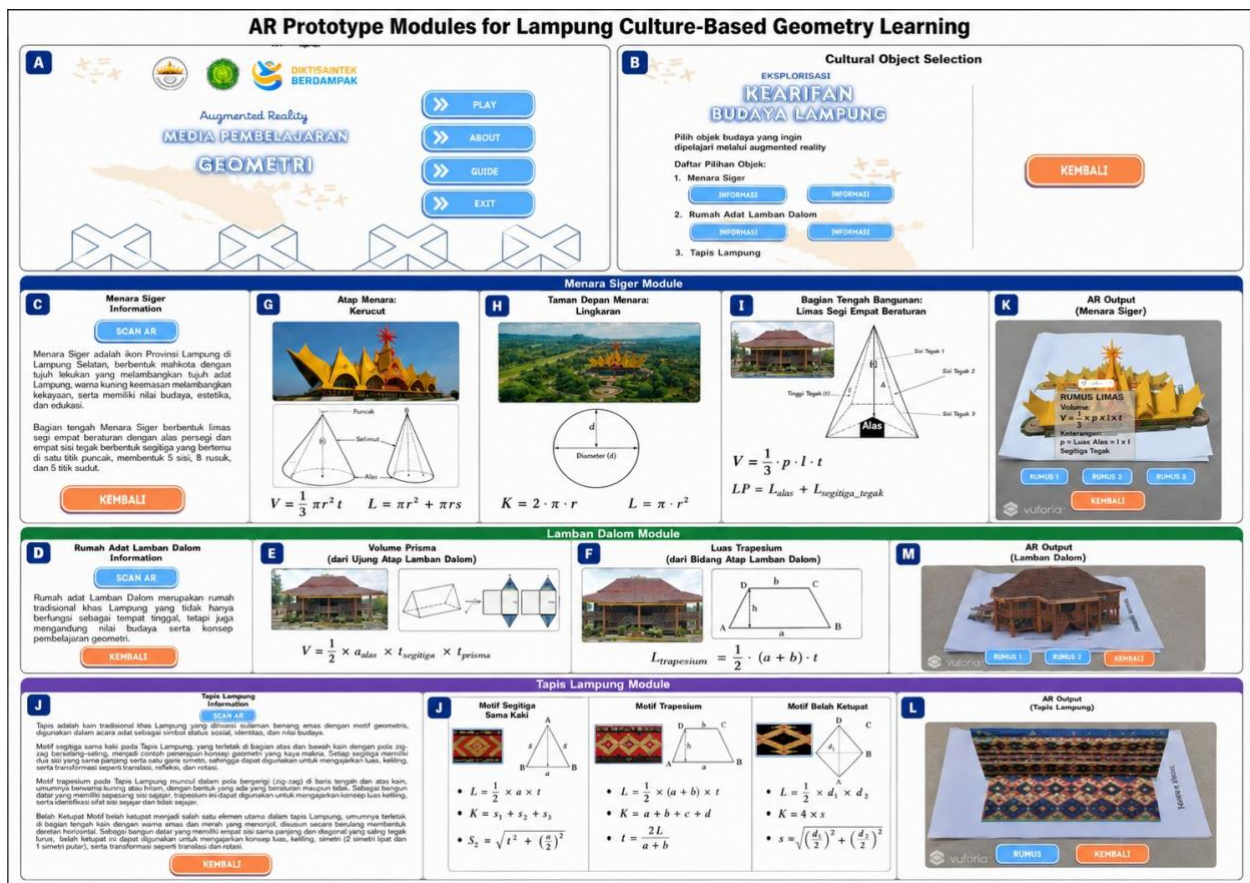


Figure 4. Display of the AR prototype in Lampung Culture-Based Geometry Learning

Figure 4 provides a detailed view of the interface and learning functions included within the AR prototype. Panel (A) shows the main menu, which gives access to the learning module, user instructions, and other supporting information. Panel (B) shows the cultural artifact selection page, where users can select *Menara Siger*, *Lamban Dalom*, or *Lampung Tapis*. *Menara Siger* learning module appears within Panel (C), (G), (H), (I), and (K). Panel (C) gives an introduction to the cultural

background of *Menara Siger*. Panels (G), (H), and (I) then explain geometric ideas based on its structural parts, including the cone, circle, and square pyramid, along with their mathematical representations. Panel (K) shows an AR view, where the user can examine *Menara Siger* as a three-dimensional representation.

Lamban Dalom module appears within Panel (D), (E), (F), and (M). Panel (D) explains the cultural meaning of the traditional house. Panels (E) and (F) then focus on the geometric forms found within the architectural parts, especially prisms and trapezoids. A three-dimensional AR view is shown in Panel (M), where the user can examine the structure of *Lamban Dalom* from different spatial views. *Lampung Tapis* module is shown in Panel (J) and (L). Panel (J) explains the cultural meaning and geometric features of the Tapis motif, including triangles, trapezoids, and rhombuses. Panel (L) provides an AR view, allowing users to explore geometric patterns that appear within textile design.

Three modules follow the same basic learning order. First, learners are introduced to the cultural background of the object. Next, they examine geometric features that can be found within it. These features then connect to formal mathematical concepts before learners explore the object through AR. This common structure shows that the prototype does not place culture and geometry in separate parts. Instead, cultural artifacts become the first object of observation, while the following geometric and AR representations gradually guide learners toward mathematical properties and spatial relationships.

The prototype shows how the EGL model can be implemented through digital representation. However, it does not prove that AR by itself can develop higher-level geometric reasoning. Interactive visualization becomes useful for learning when students ask to compare properties, describe relationships, and explain why observations are correct. This idea aligns with research based on Van Hiele theory, which explains that geometric thinking develops through the order and type of learning experience, not simply from seeing visual representation (Muhassanah et al., 2025; Yulardi & Rosjanuardi, 2021). Therefore, the next DBR cycle should examine how teachers provide scaffolding and how structured classroom activities support the intended reasoning process.

Expert Validation Results

Five experts took part in the validation process. Their expertise covers mathematics education, ethnomathematics, curriculum design, Lampung cultural study, together with augmented reality or educational technology. Having experts from these different areas allows model review from pedagogical, cultural, and technological perspectives. The validation instrument contains 27 items divided into three domains: pedagogical coherence, cultural authenticity, and technological functionality. These areas were chosen based on common principles for evaluating educational products, especially those related to design quality, content relevance, and implementation feasibility. The results of expert validation are presented in Table 3.

Table 3. Expert Validation Scores

Validator	Area of Expertise	Pedagogical Coherence	Cultural Authenticity	Technological Functionality	Composite Score	Category
V1	Mathematics Education	4.20	4.30	4.20	4.23	Highly Valid
V2	Ethnomathematics	4.10	4.20	4.10	4.13	Highly Valid
V3	Curriculum Design	4.30	4.40	4.30	4.33	Highly Valid
V4	Lampung Cultural Studies	4.00	4.30	4.15	4.15	Highly Valid
V5	Augmented Reality/Educational Technology	4.30	4.15	4.20	4.22	Highly Valid
Mean		4.18	4.27	4.19	4.21	Highly Valid

Table 3 shows that the composite score from the five validators ranges between 4.13 and 4.33. After the arithmetic mean for V4 was corrected from 4.14 to 4.15, the overall composite score remained 4.21/5.00. Based on an a priori criterion of mean score ≥ 3.75 , the EGL model is classified as highly valid at the formative design stage. Table 4 also shows that the difference between validator ratings remains small, with SD values of 0.07- 0.13 across the three domains and an overall composite SD of 0.08. This means that the high average score is not caused by one validator giving an unusually high rating. Still, findings should be understood within their limited purpose. Experts consider the design criteria strongly represented within the current framework and proof of concept. Still, these scores do not show whether the prototype is easy to use or whether it improves learning.

Cultural authenticity obtained the highest score, with $M = 4.27$ and $SD = 0.10$. One reason may be that the prototype uses Lampung cultural artifacts that have already been discussed within ethnomathematics studies. The prototype also keeps cultural narrative instead of changing the object into a general geometric example (Efendi et al., 2025; Marian & Saputra, 2023; Susiana et al., 2020). Even with a strong rating, cultural experts suggest that meanings related to cooperation, humility, and social cohesion should be explained more clearly. Pedagogical coherence has a slightly lower mean of 4.18 with $SD = 0.13$. The lower score is not because the model has no learning sequence. Rather, experts want the connection between cultural exploration, geometric analysis, formalization, and problem solving to become clearer. This issue is important when viewed through Van Hiele theory because geometric reasoning develops through properly ordered learning experiences. CTML also stresses that multimedia elements should be organized for clear learning purposes instead of simply being included within the material (Mayer, 2009; Yuliardi & Rosjanuardi, 2021). Technological functionality received $M = 4.19$ and $SD = 0.07$. However, AR experts still point out issues related to navigation, label readability, and performance on mid-range devices. This shows that expert validation cannot replace usability testing with actual users.

Table 4. Domain-Level Expert Validation Summary (n=5)

Validation Domain	Number of Items	Mean Score Across Five Experts	SD across validator	Category
Pedagogical Coherence (alignment with Van Hiele theory, CTML principles, and learning progression)	10	4.18	0.13	Highly Valid
Cultural Authenticity (accuracy of ethnomathematical content, fidelity to Lampung cultural heritage, and philosophical integration)	9	4.27	0.10	Highly Valid
Expert-Perceived Technological Functionality (AR performance, expert-perceived interface clarity, offline accessibility, and interactivity)	8	4.19	0.07	Highly Valid
Overall Composite Score	27	4.21	0.08	Highly Valid

Table 5 gives more explanation for the score report in Tables 3 and 4. The high cultural-authenticity score is supported by a comment saying that the selected artifact is appropriate. At the same time, the expert asks for a deeper explanation of the cultural meaning. The pedagogical score is somewhat lower, and comments mainly ask for a clearer explanation of the five stages and their connection with learning outcomes. The technological score is also high, but the expert still suggests improvements in navigation, readability, and device compatibility. Therefore, qualitative comments do not disagree with the quantitative results. Instead, they show which parts still need attention even though the overall rating is high. This combination of numerical and qualitative evidence is important within formative DBR because high validation scores do not mean the design should stop being revised.

Table 5. Summary of Expert Feedback

Validator	Area of Expertise	Focus of Feedback	Summary of Feedback
V1	Mathematics Education	Pedagogical coherence	The EGL-Model demonstrates a clear conceptual structure; however, the connections between cultural artifact exploration and geometry learning outcomes require further clarification.
V2	Ethnomathematics	Cultural integration	The selection of <i>Menara Siger</i> , <i>Lamban Dalom</i> , and Tapis motifs is appropriate as a source of geometric concepts; however, the cultural narratives should be enriched to ensure that they function as meaningful learning resources rather than merely visual contexts.
V3	Curriculum Design	Instructional implementation	The implementation stages of the framework should be described more explicitly to facilitate classroom application by teachers.
V4	Lampung Cultural Studies	Cultural authenticity	Greater attention should be given to preserving the philosophical meanings embedded in Lampung culture, particularly those related to cooperation, humility, and social cohesion.
V5	Augmented Reality/Educational Technology	Technological usability	The AR prototype is suitable as a proof of concept; however, improvements in navigation, label readability, and usability on mid-range devices are recommended.

The revision process was documented as an evidence-to-design chain rather than as a general statement that the model was simply “improved.” Table 6 summarizes the main changes from EGL-Model v1 to EGL-Model v2. The most substantial revisions concerned the pedagogical structure. Although EGL-Model v1 already contained the major theoretical components, the purposes of each stage and the transitions between stages required further clarification. EGL-Model v2 therefore refined the description of each stage and strengthened its relationship with Van Hiele’s geometric reasoning and CTML principles. Cultural revisions focused on distinguishing the use of cultural artifacts as mere visual examples from their use as sources of mathematical and cultural meaning. Technological revisions addressed navigation and label presentation while maintaining offline accessibility. Together, these revisions directly responded to the aspects identified by the expert panel as requiring further development.

Table 6. Traceability from Expert Feedback to EGL-Model v2 Revisions

Design issue identified	Evidence from validation	Revision decision	Change in EGL-Model v2
The links between instructional stages required further clarification	Comments from V1 and V3; pedagogical coherence obtained the lowest domain mean ($M = 4.18$)	Clarify the instructional purpose of each stage and strengthen the transition from one stage to the next	The five-stage sequence was refined as a coherent reasoning pathway from cultural artifact exploration to contextual mathematical problem solving
Cultural content risked being used mainly as a visual context	Comments from V2 and V4, despite cultural authenticity receiving the highest domain mean ($M = 4.27$)	Strengthen cultural narratives and the role of cultural value reflection	Cultural meaning was incorporated into both the exploration and reflection stages so that the artifacts function as sources of mathematical and cultural meaning rather than as introductory illustrations

Design issue identified	Evidence from validation	Revision decision	Change in EGL-Model v2
The connection between cultural representations and formal geometric concepts required further clarification	Qualitative feedback from V1 and V3	Strengthen the relationship among artifact features, geometric properties, formal concepts, and problem-solving activities.	The artifact-to-concept mapping was linked more closely to learning activities that guide students from observation and comparison toward mathematical formalization.
Navigation and label readability required refinement.	Qualitative feedback from V5	Improve interface clarity while maintaining the proof-of-concept scope	Navigation and label presentation were reorganized, while local storage and offline access were retained
The available evidence did not yet justify claims about classroom usability or instructional effectiveness	Interpretation across the validation results and the scope of the study	Limit the conclusions to expert-based content and design validity	The conclusion and implications were revised to distinguish proof-of-concept validity from usability, classroom practicality, and instructional effectiveness

Overall, findings describe a framework that receives strong expert ratings while still having several areas for further development. Earlier AR-based ethnomathematics studies often focus on media development, cultural object exploration, or needs analysis. EGL-Model adds a clearer instructional structure by connecting cultural content, geometric reasoning, multimedia design, and AR interaction, together with offline access (Gustina et al., 2025; Richardo et al., 2023; Umri et al., 2025). Its novelty, therefore, should be understood as a contribution at the design level. The study does not show that EGL-Model is better than other existing approaches. Such a claim requires classroom comparison and user-based testing.

Implications for Research and Practice

From a research perspective, EGL-Model provides a design proposition that can be tested within the next DBR cycle. Future research can examine whether teachers and students follow the five-stage sequence as planned. It can also investigate whether students actually develop from visual recognition toward analysis and informal deduction—another question concerns which AR interactions help this development and which ones may distract learners. Since the model clearly connects artifacts, geometric concepts, reasoning stages, and multimedia representations, together with interaction, future studies can also examine each design element separately instead of treating the entire AR application as a single intervention.

For teachers and curriculum developers, artifact-to-concept mapping provides one possible way to use local cultural heritage within geometry learning. Cultural objects can become a source for geometry activities instead of being added only as illustrations after the mathematical concept has already been taught. The five-stage sequence can also be used to organize lessons from cultural exploration, through formalization, and toward problem solving. In addition, CTML-based organization may help teachers avoid adding visual or verbal information that is not needed. For schools where internet access is limited, offline-first design may also become useful. However, its practical usefulness still needs to be checked on different devices and under actual school conditions (Lestari et al., 2025; Sapta et al., 2025).

This implication should still be considered preliminary. Current findings only support expert judgment about coherence, authenticity, and initial technical feasibility. A decision about wider adoption, therefore, should be made after additional testing. Teacher and student usability, implementation fidelity, and classroom outcomes need to be examined first. Future classroom study should also look toward geometric understanding, spatial reasoning, engagement, together with equal access across different school settings.

LIMITATIONS

Four main limitations should be considered. First, validation involves only five purposively selected experts. Therefore, findings represent expert-based content and design validity and cannot be treated as broadly generalizable results. Second, teachers and students are not involved in usability testing. The study does not use the System Usability Scale (SUS), task-completion tests, or user-satisfaction measures. Third, internal technical checks do not produce systematic performance data from a wide enough range of devices and school environments. Fourth, there is no classroom implementation and no measurement of geometric understanding, spatial reasoning, motivation, engagement, or implementation fidelity. The prototype also uses only three Lampung cultural artifacts, which limits the current model in terms of cultural coverage and curriculum coverage.

Future studies should first involve teachers and students in user-centered usability testing. This can include SUS assessment, observation of task completion, together with interviews about navigation and cognitive load. After this stage, pilot and field studies can examine whether the model is implemented as planned. Researchers can also compare EGL-Model-supported learning with conventional geometry instruction through experimental, quasi-experimental, or mixed-methods approaches. More studies are also needed in rural, urban, and inclusive classrooms. Adding other Lampung cultural artifacts would further help determine whether the model can transfer to different settings and whether it can produce meaningful educational results.

CONCLUSION

This study develops and validates the EGL model as a framework that combines Lampung ethnomathematics with Augmented Reality (AR) for geometry learning. The model brings together Lampung cultural artifacts, formal geometry concepts, AR visualization, and cultural narratives, together with a five-stage learning sequence. Through this structure, the geometry learning design has a stronger connection with local culture while also providing a visual and interactive learning experience. Expert validation produced an overall mean of 4.21 out of 5.00, placing the EGL-Model within the highly valid category across pedagogical, cultural, and technological domains. The score suggests that experts find the framework conceptually coherent, culturally appropriate, and technically feasible at the initial development stage. AR prototype also works as a proof of concept for three-dimensional visualization. It allows users to interact with Lampung cultural artifacts and examine geometric concepts connected to them. However, these findings do not yet show that the prototype is easy for teachers or students to use, practical in a real classroom, or effective for improving learning outcomes.

Although the results are encouraging, this study only reaches the stage of expert validation and prototype testing. The EGL-Model has not yet been tested in a real classroom situation. Because of this, its effect on students' geometric understanding, spatial reasoning, learning motivation, and engagement remains unknown. These outcomes need to be examined in future studies. Future research should test the EGL model within more diverse educational settings, including rural schools and inclusive classrooms. Researchers can also compare geometry learning support by AR and ethnomathematics with conventional geometry instruction. Experimental, quasi-experimental, or mixed-method approaches may be used to provide stronger evidence about the educational effectiveness of the framework.

AUTHOR CONTRIBUTIONS

FM was responsible for conceptualization, methodology, software development, investigation, and writing the original draft. FL handled conceptualization, validation, formal analysis, supervision, and review, together with editing of the manuscript. RJ worked on software development, visualization, and technical review. RMZ contributed to validation, data analysis, project administration, and manuscript review, together with editing. All authors reviewed the final manuscript and approved its final version.

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REFERENCES

- Abdullah, A. A., Richardo, R., Rochmadi, T., Wijaya, A., & Nurkhamid, N. (2022). The use of ethnomathematics learning media based on augmented reality for madrasah students. *AL-ISHLAH: Jurnal Pendidikan*, 14(1), 877–886. <https://doi.org/10.35445/alishlah.v14i1.1140>
- Akindele, B. O. (2025). Application of design-based research in innovative education: Western African education perspectives. In R. A. Razak, N. F. Alias, & A. Y. Idris (Eds.), *Global perspectives and implementations of design-based research* (pp. 101–134). IGI Global Scientific Publishing. <https://doi.org/10.4018/979-8-3373-2086-1.ch004>
- Alkharusi, H. A., Sulaimani, H. A., & Neisler, O. (2019). Predicting critical thinking ability of Sultan Qaboos University students. *International Journal of Instruction*, 12(2), 491–504. <https://doi.org/10.29333/iji.2019.12231a>
- Asrifan, A., Sadaruddin, S., Sahabuddin, R., Rahman, F. A., Herlina, H., & Saodi, S. (2025). The evolution of design-based research: Future perspectives and trends. In R. A. Razak, N. F. Alias, & A. Y. Idris (Eds.), *Global perspectives and implementations of design-based research* (pp. 355–386). IGI Global Scientific Publishing. <https://doi.org/10.4018/979-8-3373-2086-1.ch011>
- Atmaja, I. M. D., Puspawati, K. R., & Payadnya, I. P. A. A. (2025). Ethnomathematics as a pillar of ethnopädagogie in STEM: A case study of mathematics education students' critical understanding. *Jurnal Pendidikan Progresif*, 15(4), 2403–2420. <https://doi.org/10.23960/jpp.v15i4.pp2403-2420>
- Barab, S. (2022). Design-based research: A methodological toolkit for engineering change. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 177–195). Cambridge University Press. <https://doi.org/10.1017/9781108888295.012>
- Cetintav, G., & Yilmaz, R. (2023). The effect of augmented reality technology on middle school students' mathematics academic achievement, self-regulated learning skills, and motivation. *Journal of Educational Computing Research*, 61(7), 1483–1504. <https://doi.org/10.1177/07356331231176022>
- Cochrane, T., Galvin, K., Glasser, S., Osborne, M., Buskes, G., & Rajagopal, V. (2024). Exploring design-based research as a framework for addressing pedagogical problems faced by higher education: A panel discussion. *ASCILITE Publications*, 171–173. <https://doi.org/10.14742/apubs.2024.1335>
- Efendi, D., Marian, F., Lestari, F., Zain, R. M., & Ramadhani, S. (2025). Eksplorasi potensi etnomatematika Lampung sebagai dasar pengembangan modul pembelajaran geometri berbasis augmented reality. *Jurnal Pendidikan Matematika Malikussaleh*, 5(4), 456–470. <https://doi.org/10.29103/jpmm.v5i4.22987>
- Firdausi, A. R. (2025). Utilization of mobile-based learning media to improve education accessibility in remote areas. *Journal of Pedagogi*, 2(3), 95–104. <https://doi.org/10.62872/h4kwy819>
- Flores-Bascuñana, M., Diago, P. D., Villena-Taranilla, R., & Yáñez, D. F. (2020). On augmented reality for the learning of 3D-geometric contents: A preliminary exploratory study with 6-grade primary students. *Education Sciences*, 10(1), Article 4. <https://doi.org/10.3390/educsci10010004>
- Flynn, P., McHugh, M., McCauley, V., & Hall, T. (2022). Design-based research. In T. Delahunty & M. Ní Ríordáin (Eds.), *Perspectives in contemporary STEM education research: Research methodology and design* (pp. 92–100). Routledge. <https://doi.org/10.4324/9781003108122-11>
- Gilligan-Lee, K. A., Hawes, Z. C. K., & Mix, K. S. (2022). Spatial thinking as the missing piece in mathematics curricula. *npj Science of Learning*, 7, Article 10. <https://doi.org/10.1038/s41539-022-00128-9>
- Gustina, D. M., Mariana, N., & Wiryanto. (2025). Augmented reality-based ethnomathematics learning media to enhance spatial ability in 3D geometry for fifth grade elementary students. *Journal of Innovation and Research in Primary Education*, 4(2), 273–280. <https://doi.org/10.56916/jirpe.v4i2.1229>

- Hafid, H., & Barnoto, B. (2022). Manajemen pembelajaran kelas digital berbasis Google Workspace for education. *Kharisma: Jurnal Administrasi dan Manajemen Pendidikan*, 1(1), 48–58. <https://doi.org/10.59373/kharisma.v1i1.5>
- Hakim, M. N., & Abidin, A. A. (2024). Platform merdeka mengajar: Integrasi teknologi dalam pendidikan vokasi dan pengembangan guru. *Kharisma: Jurnal Administrasi dan Manajemen Pendidikan*, 3(1), 68–82. <https://doi.org/10.59373/kharisma.v3i1.47>
- Juliani, R. P., & Erita, S. (2023). Analisis validitas dan reliabilitas instrumen penilaian kemampuan berpikir kritis dalam konteks sekolah menengah. *JEID: Journal of Educational Integration and Development*, 3(3), 169–179. <https://doi.org/10.55868/jeid.v3i3.313>
- Kim, H.-J. (2020). Concreteness fading strategy: A promising and sustainable instructional model in mathematics classrooms. *Sustainability*, 12(6), Article 2211. <https://doi.org/10.3390/su12062211>
- Lestari, F., Noprisa, N., Cahyani, J. D., & Wibowo, D. S. (2026). Digital augmented reality flipbook based on local wisdom: An instructional innovation to enhance students' mathematical literacy. *Jurnal Pendidikan Matematika dan Sains*, 14(1), 36–45. <https://doi.org/10.21831/jpms.v14i1.88197>
- Loviana, S., Merliza, P., Damayanti, A., Mahfud, M. K., & Islamuddin, A. M. (2020). Etnomatematika pada kain tapis dan rumah adat Lampung. *Tapis: Jurnal Penelitian Ilmiah*, 4(1), 94–110. <https://doi.org/10.32332/tapis.v4i1.1956>
- Mackiewicz, J. (2018). A mixed-method approach. In *Writing center talk over time: A mixed-method study* (pp. 37–60). Routledge. <https://doi.org/10.4324/9780429469237-3>
- Marian, F., & Saputra, D. R. (2023). Etnomatematika pada Menara Siger Lampung sebagai bahan pembelajaran matematika. *JIPMat*, 8(2), 191–200. <https://doi.org/10.26877/jipmat.v8i2.16017>
- Mayer, R. E. (2009). *Multimedia learning*. Cambridge University Press. <https://doi.org/10.1017/CBO9780511811678>
- McKenney, S., & Reeves, T. C. (2019). *Conducting educational design research* (2nd ed.). Routledge. <https://doi.org/10.4324/9781315105642>
- Mkwizu, K. H., & Bordoloi, R. (2024). Augmented reality for inclusive growth in education: The challenges. *Asian Association of Open Universities Journal*, 19(1), 88–100. <https://doi.org/10.1108/AAOUJ-09-2023-0113>
- Muhammad, H., Musa, N. A., Ahmad, A., Adamu, N., & Adamu, N. (2026). The role of augmented reality (AR) in enhancing conceptual understanding of geometry in mathematics education: Systematic review. *International Journal of Education, Management, and Technology*, 4(1), 29–47. <https://doi.org/10.58578/ijemt.v4i1.8073>
- Muhassanah, N., Nuha, M. 'A. M., & Aspriyani, R. (2025). Teachers' experiences with students' learning obstacles in geometric thinking: Insights from the van Hiele framework. *International Journal of Research in Mathematics Education*, 3(2), 203–216. <https://doi.org/10.24090/ijrme.v3i2.15429>
- Mumu, J., Tanujaya, B., Charitas, R., & Prahmana, I. (2022). Likert scale in social sciences research: Problems and difficulties. *FWU Journal of Social Sciences*, 16(4), 89–101. <https://doi.org/10.51709/19951272/Winter2022/7>
- Mygdanis, Y. (2025). Design-based research in music education: Theoretical foundations, methodological perspectives, and practice implications. *Futurity Education*, 5(2), 90–114. <https://doi.org/10.57125/FED.2025.06.25.05>
- Noprisa, N., Lestari, F., Hardianti, D., Desmayanasari, S. A. A. D., Efendi, D., Rizko, D., & Kurnia, E. (2024). Traditional house of Lampung Kedatun Keagungan: Ethnomathematics exploration. *Inomatika*, 6(1). <https://doi.org/10.35438/inomatika.v6i1.417>
- Parandreni, M. J. (2024). Development of an augmented reality-based geometry module to enhance students' understanding of three-dimensional concepts. *Aksioma Education Journal*, 1(2), 44–54. <https://doi.org/10.62872/chh9qw39>
- Richardo, R., Wijaya, A., Rochmadi, T., Abdullah, A. A., Nurkhamid, Astuti, A. W., & Hidayah, K. N. (2023). Ethnomathematics augmented reality: Android-based learning multimedia to improve creative thinking skills on geometry. *International Journal of Information and Education Technology*, 13(4), 731–737. <https://doi.org/10.18178/ijiet.2023.13.4.1860>

- Rosa, M., & Shirley, L. (2016). In guise of conclusion. In *Current and future perspectives of ethnomathematics as a program* (pp. 39–40). https://doi.org/10.1007/978-3-319-30120-4_4
- Rossano, V., Lanzilotti, R., Cazzolla, A., & Roselli, T. (2020). Augmented reality to support geometry learning. *IEEE Access*, 8, 107772–107780. <https://doi.org/10.1109/ACCESS.2020.3000990>
- Sapta, A., Risnawati, E., Panjaitan, D. J., Marisa, & Nisa, U. K. (2025). Development of augmented reality media for local wisdom learning. *Journal of Informatics and Vocational Education*, 9(4). <https://doi.org/10.62527/joiv.9.4.4359>
- Silva, N. O., & Da Silva, D. D. R. (2011). Bases epistemológicas das relações entre cultura e educação matemática. *Amazônia: Revista de Educação em Ciências e Matemáticas*, 7(13), 1–22. <https://doi.org/10.18542/amazrecm.v7i0.1691>
- Susiana, Caswita, & Noer, S. H. (2020). Ethnomathematics: Mathematical concepts in Tapis Lampung. *Journal of Physics: Conference Series*, 1581(1), Article 012056. <https://doi.org/10.1088/1742-6596/1581/1/012056>
- Ulfah, M., Syamsi, A., Dewi, E. W., Luhanarky, A., & Hadiana, D. (2026). Does transformative digital learning management enhance the sustainability of inclusive Islamic education? Evidence from diaspora children in Australia. *Kharisma: Jurnal Administrasi dan Manajemen Pendidikan*, 5(1), 32–47. <https://doi.org/10.59373/kharisma.v5i1.151>
- Umri, B. K., Rahman, A. Z., & Aini, A. N. (2025). Pengembangan media pembelajaran etnomatematika Candi Prambanan berbasis augmented reality untuk materi geometri. *Jurnal Teknologi Informasi dan Ilmu Komputer*, 12(2), 301–310. <https://doi.org/10.25126/jtiik.2025129330>
- Vásquez Hidalgo, G. D. R., Simbaña Tupiza, L. P., Paredes Ochoa, I. M., Morales Castellanos, M. B., & Villares Gaviláñez, S. S. (2025). Impacto de la realidad aumentada en la comprensión aritmético-espacial de conceptos geométricos en estudiantes de 10 a 12 años. *LATAM Revista Latinoamericana de Ciencias Sociales y Humanidades*, 6(3). <https://doi.org/10.56712/latam.v6i3.3983>
- Yuliardi, R., & Rosjanuardi, R. (2021). Hypothetical learning trajectory in student's spatial abilities to learn geometric transformation. *JRAMathEdu*, 6(3), 174–190. <https://doi.org/10.23917/jramathedu.v6i3.13338>