JLJ 14 (4) 2025

**Joyful Learning Journal**

https://journal.unnes.ac.id/sju/index.php/jlj


# DESIGNING A PROTOTYPE OF MATHEMATICS LEARNING MEDIA BASED ON AUGMENTED REALITY INTEGRATED WITH PROBLEM BASED LEARNING IN AN ETHNOMATHEMATICS CONTEXT

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**Info Artikel**

*Sejarah Artikel:*

Diterima **Juli 2026**
Disetujui **Juli 2026**
Dipublikasikan **Juli 2026**

*Keywords: Augmented Reality, Problem Based Learning, Ethnomathematics, Elementary Mathematics, Geometry, Conceptual Prototype*

## Abstrak

Pembelajaran matematika di sekolah dasar Indonesia menghadapi tantangan yang terus berlanjut, terutama pada materi geometri, di mana siswa kesulitan mengenali sifat-sifat bangun datar dan menerapkan konsepnya dalam konteks kehidupan nyata. Kesulitan ini bersumber dari pembelajaran yang berpusat pada guru dan media statis yang menawarkan interaktivitas serta relevansi kontekstual yang terbatas, sehingga menyebabkan rendahnya motivasi dan lemahnya pemahaman konseptual siswa. Augmented Reality (AR) dapat mengatasi hal ini melalui visualisasi interaktif objek geometri, sementara Problem Based Learning (PBL) menyediakan kerangka pembelajaran kolaboratif dan pemecahan masalah autentik. Integrasi keduanya dengan etnomatematika yang menghubungkan matematika dengan budaya lokal dapat meningkatkan keterlibatan dan kebermaknaan belajar. Penelitian ini bertujuan merancang prototipe konseptual media pembelajaran matematika berbasis AR yang terintegrasi dengan PBL dalam konteks etnomatematika untuk materi bangun datar kelas V (persegi, persegi panjang, segitiga, dan lingkaran). Metode deskriptif kualitatif digunakan melalui analisis kebutuhan, kurikulum, dan konsep berdasarkan kajian literatur serta dokumen Kurikulum Merdeka. Temuan menunjukkan bahwa media yang ada belum mengintegrasikan teknologi interaktif, pemecahan masalah kontekstual, dan relevansi budaya secara memadai. Berdasarkan temuan tersebut, dirancanglah prototipe konseptual bernama ETMAR (Ethnomathematics Augmented Reality) sebagai platform berbasis web yang dapat diakses melalui laptop dan perangkat seluler. Prototipe ini menampilkan visualisasi model 3D interaktif pada laptop dan visualisasi AR pada perangkat seluler, dengan mengkontekstualisasikan bangunan bersejarah Semarang Lawang Sewu, Tugu Muda, dan Gereja Blenduk sebagai konteks etnomatematika dalam skenario masalah berbasis PBL untuk materi bangun datar. Prototipe ini diharapkan menjadi fondasi teoretis bagi pengembangan lebih lanjut, validasi ahli, dan implementasi di kelas.

## *Abstract*

*Mathematics learning in Indonesian elementary schools faces persistent challenges, particularly in geometry, where students struggle to recognize plane figure properties and apply concepts to real-life contexts. These difficulties stem from teacher-centered instruction and static media that offer limited interactivity and contextual relevance, leading to low motivation and weak conceptual understanding. Augmented Reality (AR) can address this through interactive visualization of geometric objects, while Problem Based Learning (PBL) provides a collaborative, authentic problem-solving framework. Integrating both with ethnomathematics which links mathematics to local culture can enhance engagement and meaningfulness. This study aims to design a conceptual prototype of AR-based mathematics learning media integrated with PBL in an ethnomathematics context for Grade V plane geometry (squares, rectangles, triangles, and circles). A qualitative descriptive method was employed through needs, curriculum, and concept analyses based on literature and Merdeka Curriculum documents. Findings reveal that existing media lack integration of interactive technology, contextual problem-solving, and cultural relevance. Consequently, a conceptual prototype named ETMAR (Ethnomathematics Augmented Reality) was designed as a web-based platform accessible on laptops and mobile devices. It features interactive 3D model visualization on laptops and AR visualization on mobile devices, contextualizing Semarang's historical landmarks Lawang Sewu, Tugu Muda, and Gereja Blenduk as ethnomathematics contexts within PBL-based problem scenarios for plane geometry. This prototype provides a theoretically grounded foundation for future development, expert validation, and classroom implementation.*



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P-ISSN 2252-6366 | E-ISSN 2775-295X

## INTRODUCTION

Mathematics learning in Indonesia continues to face serious challenges that demand immediate and systemic attention. The results of the 2022 PISA (Programme for International Student Assessment) survey revealed that Indonesian students scored 366 points in mathematics, significantly below the OECD average of 472 points, placing Indonesia 70th out of 81 participating countries (OECD, 2023). More concerning, this score represents a decline from the 2018 result of 379 points, indicating that students' mathematical literacy has not only stagnated but regressed. These figures reflect a persistent and structural problem in how mathematics is taught and experienced by Indonesian students across all levels, including at the elementary school level where foundational mathematical understanding is first established. Poor mathematical literacy at the elementary level creates compounding difficulties in subsequent years, as students who fail to develop strong conceptual foundations in early mathematics are likely to struggle with more advanced content later in their education (Geary, 2011).

The root of this challenge lies in learning approaches that remain largely conventional, teacher-centered, and heavily reliant on memorization and repetitive exercises that hold little meaning for students (Permatasari, 2021). In most Indonesian elementary classrooms, mathematics is presented as a fixed set of procedures and formulas to be memorized and applied mechanically, with little emphasis on conceptual understanding, contextual relevance, or the development of higher-order thinking skills (Rahayu Sesanti & Arifin, 2025). As a result, many students perceive mathematics as a difficult, abstract, and irrelevant subject disconnected from their daily lives, breeding negative attitudes and poor motivation that ultimately undermine learning outcomes (Anggreini & Priyojadmiko, 2022). Meaningful learning experiences require students to actively construct mathematical knowledge through exploration, discussion, and reflection rather than merely receiving information from teachers. Consequently, innovative instructional approaches that promote active engagement are increasingly necessary to improve students' understanding and motivation in elementary mathematics (Ni et al., 2026).

The challenges of conventional mathematics learning are particularly pronounced in geometry, one of the core content areas in elementary school mathematics. At the Grade V level, students are expected to identify and distinguish the properties of plane geometric figures including squares, rectangles, triangles, and circles calculate their perimeter and area, and apply these concepts in contextual problem-solving situations. However, many students experience persistent difficulties in meeting these expectations. Students often struggle to distinguish the characteristics of different plane figures, connect geometric properties to real-life objects, and transfer formula knowledge to authentic problem contexts (Syafril et al., 2021). These difficulties are largely attributable to instruction that relies exclusively on static textbook illustrations and verbal explanation, which offers limited opportunities for students to observe, manipulate, or interact with geometric shapes (Schleppegrell, 2010). Furthermore, elementary school students are generally in the concrete operational stage of cognitive development, meaning they construct understanding most effectively through direct interaction with concrete objects and visual representations rather than through abstract symbolic instruction alone (Berk, 2018; Piaget & Inhelder, 1969). This developmental characteristic makes the provision of interactive, visually rich learning media particularly important at this level.

The rapid advancement of digital technology has opened enormous opportunities to transform mathematics learning into something more interactive, contextual, and meaningful (Jaya et al., 2024). One of the technologies rapidly developing in education is Augmented Reality (AR), a technology that enables the interactive display of virtual objects overlaid on the real world through mobile devices (Al-Ansi et al., 2023). Unlike conventional instructional media, AR allows students to visualize and interact with virtual representations of geometric figures in real time, making abstract concepts more concrete and accessible (Latif et al., 2024). Students can observe plane figures from different angles, identify their sides and angles interactively, and explore geometric properties in ways that static media cannot provide. The use of AR in mathematics learning, particularly in geometry, has consistently shown positive results by allowing students to engage directly with geometric objects in a visual and interactive manner (Marian et al., 2025; Voulgari et al., 2024). Moreover, the widespread accessibility of smartphones among Indonesian students creates promising opportunities for implementing AR-based learning media in elementary classrooms without requiring expensive dedicated equipment (APJII, 2024).

However, technology alone is insufficient without an appropriate learning model to structure how students engage with it. Problem Based Learning (PBL) is a student-centered learning model that emphasizes collaborative real-world problem solving (Hidayah et al., 2021). Rooted in constructivist learning theory, PBL positions students as active constructors of knowledge, engaging them in analyzing authentic problems, formulating strategies, investigating solutions, and communicating findings (Hmelo-Silver, 2004). Rather than presenting geometric concepts through direct explanation, PBL challenges students to discover and construct understanding by working through meaningful problems that require the application of geometric knowledge. The integration of AR with PBL is therefore considered capable of creating deeper and more lasting learning experiences, as students not only observe geometric figures through AR but also actively think, investigate, and solve problems through interaction with AR visualizations. This combination aligns strongly with the demands of 21st-century skills encompassing critical thinking, creativity, collaboration, and communication (Thornhill-Miller et al., 2023), and is consistent with the goals of Indonesia's Merdeka Belajar curriculum framework, which emphasizes student agency, contextual learning, and the development of transferable competencies.

Beyond technology and learning models, cultural context plays a critical role in creating meaningful mathematics learning experiences. Ethnomathematics, as an approach that integrates local cultural elements into mathematics learning, has been proven to enhance student motivation, engagement, and conceptual understanding (Andriono, 2021; Vitoria et al., 2021). By connecting geometric concepts to cultural contexts already familiar and meaningful to students such as the architectural forms found in traditional buildings, the patterns of local crafts, or the shapes embedded in historical landmarks learning becomes more relevant and less alienated from students' everyday lives (Alghar & Radjak, 2024). In the Indonesian context, where cultural heritage is immensely rich and diverse, ethnomathematics offers an abundant source of authentic geometric contexts. The historical city of Semarang, for instance, is home to iconic landmarks such as Lawang Sewu, Tugu Muda, and Gereja Blenduk, whose architectural features naturally embody the plane geometric shapes studied at the Grade V level. Integrating these landmarks into mathematics learning not only provides authentic geometric contexts but also fosters students' appreciation of their local cultural heritage, supporting the development of culturally responsive learning environments (Achille & Fiorillo, 2022).

Despite the recognized potential of AR, PBL, and ethnomathematics individually, an integrated mathematics learning media combining all three components for plane geometry at the elementary school level has not yet been developed. Research on AR in mathematics education has largely focused on secondary school geometry without exploiting cultural contexts, while ethnomathematics studies have rarely produced technology-based learning products. This gap constitutes the primary motivation for this study. Therefore, this study aims to produce a conceptual prototype design of mathematics learning media based on AR integrated with PBL in an ethnomathematics context for Grade V elementary school students on plane geometry content, grounded in systematic needs, curriculum, and concept analysis. The resulting prototype is expected to serve as a theoretically grounded foundation for subsequent application development, expert validation, and classroom implementation.

## RESEARCH METHOD

This study employed a qualitative descriptive method using a design study approach to develop a conceptual prototype of mathematics learning media based on Augmented Reality (AR) integrated with Problem Based Learning (PBL) in an ethnomathematics context. The study focused on producing a theoretically grounded prototype through systematic analysis rather than developing a complete application. This approach was chosen because the primary objective of the research was to formulate an initial design based on literature findings and curriculum requirements. The prototype produced in this study is expected to become the basis for further stages of research, including product development, expert validation, and field testing. According to Richey & Klein (2007), design studies are appropriate for generating educational product designs based on systematic theoretical analysis.

The data used in this study consisted entirely of secondary data obtained from scientific journal articles, official curriculum documents, and elementary mathematics textbooks. Journal articles discussing Augmented Reality, Problem Based Learning, ethnomathematics, and geometry learning published between 2021 and 2025 were reviewed systematically. In addition, curriculum documents from the Indonesian Merdeka Curriculum were analyzed to ensure that the proposed prototype aligned with current learning objectives for Grade V elementary school students. The study was conducted through four stages, namely needs analysis, curriculum analysis, concept analysis, and prototype design.

### 2.1 Needs Analysis

The needs analysis was conducted to identify the main problems encountered in elementary geometry learning and to determine the necessity of developing AR-based learning media. A literature review was carried out to examine previous studies discussing students' learning difficulties, the limitations of existing instructional media, and the implementation of AR, PBL, and ethnomathematics in mathematics education. Particular attention was given to studies reporting students' difficulties in recognizing geometric figures, understanding their properties, and solving contextual geometry problems. The analysis also explored how interactive technology and contextual learning could address these challenges. The findings from this stage were used to formulate the educational problems that should be accommodated in the proposed prototype.

**2.2 Curriculum Analysis**

Curriculum analysis was conducted to examine the suitability of the proposed learning media with the Indonesian elementary mathematics curriculum. The analysis focused on the learning outcomes for Grade V geometry in the Merdeka Curriculum, particularly those related to identifying plane geometric figures, understanding their properties, and solving contextual problems involving perimeter and area. In addition to the curriculum documents, elementary mathematics textbooks were also reviewed to identify the scope and sequence of learning materials. This stage ensured that the content included in the prototype corresponded with national curriculum standards and could support classroom learning objectives. The results of the curriculum analysis served as the basis for determining the learning content incorporated into ETMAR.

**2.3 Concept Analysis**

Concept analysis was conducted to identify the essential mathematical concepts that should be represented in the learning media and to determine appropriate ethnomathematical contexts. The concepts analyzed included squares, rectangles, triangles, and circles, together with their properties, perimeter, and area. Relevant Indonesian cultural buildings representing these geometric concepts were identified through literature studies. The relationships between mathematical concepts and cultural objects were then mapped to determine suitable contexts for AR visualization and problem-based learning activities. This analysis ensured that both mathematical accuracy and cultural relevance were integrated into the conceptual prototype.

**2.4 Prototype Design**

The final stage involved synthesizing the findings from the previous analyses to develop the conceptual prototype named ETMAR (Ethnomathematics Augmented Reality). The web-based learning media prototype accessible on laptops and mobile devices, integrating interactive AR visualization, ethnomathematics contexts, and Problem Based Learning activities. The design includes learning objectives, AR features, contextual problem scenarios, interactive learning activities, and concept reinforcement components. Since this study focused on conceptual design, the prototype has not yet been implemented or validated in classroom settings. Future studies are expected to continue with application development, expert validation, and field testing to evaluate the prototype's validity, practicality, and effectiveness.

## RESULT AND DISCUSSION

**3.1 Needs Analysis**

**3.1.1 Student Difficulties in Plane Geometry**

The literature consistently indicates that geometry remains one of the most challenging mathematics topics for elementary school students. Unlike arithmetic, geometry requires students to identify shapes, recognize their properties, and apply geometric concepts to real-life situations. Previous studies reported that many students experience difficulties distinguishing the characteristics of plane figures, calculating perimeter and area correctly, and relating geometric concepts to objects in their surroundings. These difficulties are largely caused by students' limited conceptual understanding, which often results from instruction emphasizing formula memorization rather than conceptual exploration.

In addition, elementary school students are generally in the concrete operational stage of cognitive development. At this stage, students understand mathematical concepts more effectively when learning activities involve concrete objects, visual representations, and direct experiences. However, geometry instruction in many classrooms still relies heavily on textbook illustrations and verbal explanations. Consequently, students frequently struggle to imagine the relationships among geometric elements because they have limited opportunities to manipulate or observe geometric objects from different perspectives.

The literature also indicates that students tend to regard geometry as an abstract topic that is disconnected from their daily experiences. Learning activities often emphasize procedural exercises without providing meaningful contexts that enable students to understand the practical value of geometry. As a result, students demonstrate low learning motivation and encounter difficulties when solving contextual problems requiring conceptual reasoning rather than direct formula application. These findings suggest that elementary geometry learning requires instructional media capable of presenting mathematical concepts in a more concrete, interactive, and meaningful manner.

**Table 1**. Summary of Students' Difficulties in Elementary Geometry Learning

| Learning Aspect | Problems Identified | Implications for Learning Media |
|---|---|---|
| Shape recognition | Students have difficulty distinguishing the characteristics of geometric figures (Syafril et al., 2021). | Learning media should provide clear visual representations of each shape. |
| Conceptual understanding | Students tend to memorize formulas without understanding geometric concepts (Permatasari, 2021). | Interactive activities are needed to strengthen conceptual understanding. |
| Contextual application | Students experience difficulties solving geometry problems in everyday contexts (Anggreini & Priyojadmiko, 2022). | Learning should integrate authentic and contextual problems. |
| Learning motivation | Geometry is often perceived as abstract and less interesting. | Learning media should increase students' engagement through interactive technology. |

Table 1 summarizes the major learning difficulties identified from the literature review. The findings indicate that students' problems are not limited to procedural skills but also involve conceptual understanding, visualization, and contextual application. These findings confirm the necessity of developing innovative learning media capable of addressing these learning challenges simultaneously.

### 3.1.2 Limitations of Existing Learning Media

The review of previous studies shows that learning media used in elementary geometry classrooms remain predominantly conventional. Textbooks, printed worksheets, and teacher explanations continue to serve as the primary instructional resources. Although these materials provide the basic mathematical content required by the curriculum, they offer limited opportunities for students to actively explore geometric concepts through visualization and interaction.

Several studies also report that physical teaching aids are available in some schools; however, their use remains relatively limited due to availability, maintenance, and classroom management constraints. Moreover, conventional learning media generally present geometry independently from students' cultural environments, reducing opportunities for contextual learning. Consequently, students often fail to recognize that geometric concepts are embedded in everyday cultural objects surrounding them.

Another limitation identified from the literature is the lack of instructional media integrating technology with student-centered learning models. Existing digital learning resources often focus primarily on content presentation without encouraging collaborative investigation, contextual problem solving, or active exploration. These limitations indicate the need for innovative learning media integrating visualization technology, meaningful learning activities, and contextual cultural experiences.

**Table 2**. Limitations of Existing Geometry Learning Media

| Existing Media | Strengths | Limitations |
|---|---|---|
| Textbooks | Easy to use and widely available | Static illustrations, limited visualization |
| Worksheets | Support practice activities | Focus mainly on procedural exercises |
| Physical manipulatives | Provide concrete learning experiences | Limited quantity and difficult to |

| | | |
|---|---|---|
| Digital presentations | Attractive visual appearance | use individually Mostly passive and lack interactivity |

These limitations have been widely documented in studies on mathematics learning at the elementary level (Anggreini & Priyojadmiko, 2022; Permatasari, 2021). As presented in Table 2, most existing instructional media still emphasize information delivery rather than interactive learning experiences. Consequently, students have limited opportunities to explore geometric concepts actively or relate them to meaningful contexts.

#### 3.1.3 Educational Potential of AR, PBL, and Ethnomathematics

Previous studies consistently demonstrate that Augmented Reality can significantly improve students' understanding of geometry by providing interactive visualization of mathematical objects. Through AR technology, students can observe and manipulate virtual objects directly using mobile devices, allowing abstract concepts to become more concrete and easier to understand. Such interactive experiences have been reported to increase students' engagement, learning motivation, and conceptual understanding (Mulianti et al., 2023a).

Problem Based Learning complements AR by providing a pedagogical framework that encourages students to solve authentic problems collaboratively. Rather than passively receiving information, students actively construct mathematical knowledge through investigation, discussion, and reflection. This learning process supports the development of higher-order thinking skills, including critical thinking, creativity, collaboration, and communication.

Meanwhile, ethnomathematics enriches mathematics learning by connecting mathematical concepts with students' local cultural environments. Indonesian cultural objects and local landmarks, such as the historical buildings of Semarang, batik motifs, traditional crafts, and woven bamboo objects, naturally contain various geometric forms that can be explored during learning activities. Integrating these cultural contexts into AR-based learning is expected not only to improve conceptual understanding but also to strengthen students' appreciation of local culture (Lestari et al., 2021). Therefore, the integration of AR, Problem Based Learning, and ethnomathematics provides a strong theoretical foundation for designing the ETMAR conceptual prototype.

**Table 3**. Contributions of AR, PBL, and Ethnomathematics

| **Component** | **Contribution to Learning** |
|---|---|
| Augmented Reality | Provides interactive visualization of geometric figures. (Al-Ansi et al., 2023; Marian et al., 2025) |
| Problem Based Learning | Develops critical thinking and contextual problem-solving skills (Hidayah et al., 2021; Mulianti et al., 2023b). |
| Ethnomathematics | Connects mathematics with students' local culture and daily experiences (Andriono, 2021). |
| Integration of the Three Approaches | Creates interactive, contextual, and meaningful learning experiences (Wibowo et al., 2021). |

Table 3 illustrates that each component contributes different educational advantages. Their integration provides complementary support in improving conceptual understanding, contextual learning, and student engagement, which become the basis for designing the ETMAR conceptual prototype.

### 3.2 Curriculum Analysis

Curriculum analysis was conducted to ensure that the proposed ETMAR prototype aligns with the learning objectives of the Indonesian Merdeka Curriculum for Grade V elementary school mathematics. The analysis referred to Kemendikbudristek (2024b) concerning the national curriculum framework, and Kemendikbudristek (2024a) concerning the Learning Outcomes (Capaian Pembelajaran) for all levels of education (Kemendikbudristek, 2024a; Kemendikbudristek, 2024b).

Grade V elementary school mathematics falls within Phase C of the Merdeka Curriculum. The geometry element of Phase C states that students are expected to: (1) determine the perimeter and area of various plane figures (triangles, quadrilaterals, and polygons) and their combinations; (2) compare the characteristics of plane figures and solid figures; and (3) construct and decompose solid figures while recognizing spatial visualization. At the end of Grade V specifically, students are expected to determine the perimeter and area of various plane figures including triangles and quadrilaterals, and their combinations, as well as compare characteristics among plane figures.

**Table 4**. Alignment of Phase C (Grade V) Geometry Learning Outcomes with ETMAR

| Learning Outcome | Phase C (Grade V) Description | ETMAR Alignment |
|---|---|---|
| Measurement | Determine the perimeter and area of plane figures and composite shapes. | PBL problems using Semarang historical landmarks. |
| Geometry | Compare the properties of plane and solid figures. | AR supports visual comparison of geometric shapes. |
| Geometry | Construct, decompose, and visualize solid figures. | AR 3D models enhance spatial visualization. |
| Contextual Application | Solve contextual problems involving plane figures. | Authentic PBL scenarios based on local cultural contexts. |

The analysis reveals that the Merdeka Curriculum emphasizes conceptual understanding over procedural memorization, and prioritizes contextual, student-centered learning that connects mathematical concepts to real-world situations. This is explicitly reflected in the curriculum's learning design principles, which state that learning should be meaningful, relevant, and encourage students to actively construct knowledge (Kemendikbudristek, 2024a). These principles are entirely consistent with the three core components of ETMAR: AR provides concrete visualization, PBL provides contextual problem solving, and ethnomathematics provides culturally meaningful real-world connections.

Furthermore, the curriculum's emphasis on comparing characteristics among plane figures and applying concepts to everyday situations creates a natural opening for ethnomathematics integration. The historical landmarks of Semarang Lawang Sewu, Tugu Muda, and Gereja Blenduk provide authentic contexts where rectangular windows, circular bases, and triangular roof ornaments can be explored as genuine geometric applications.

Based on a review of local cultural heritage literature and the architectural features of Semarang's historical landmarks (Achille & Fiorillo, 2022; Wibowo et al., 2021), the following mapping was established.

**Table 5**. Alignment Between ETMAR Features and Merdeka Curriculum Principles

| Merdeka Curriculum Principle | ETMAR Feature | Alignment |
|---|---|---|
| Student-centered learning | Five-stage PBL learning flow | High |
| Meaningful essential content | Plane geometry through cultural landmarks | High |
| Contextual learning | Semarang historical buildings as learning contexts | High |
| Global Diversity Profile | Ethnomathematics approach | High |

### 3.3 Concept Analysis

Concept analysis was conducted to identify the essential geometry concepts that should be incorporated into the conceptual prototype. The analysis focused on the mathematical characteristics of four plane geometric figures commonly introduced in Grade V, namely squares, rectangles, triangles, and circles. Each concept was examined based on its defining properties, perimeter, area, and relationships with objects commonly found in students' daily lives.

Following the identification of mathematical concepts, potential ethnomathematical contexts were explored through a review of Indonesian local cultural objects and historical landmarks. Numerous traditional objects naturally represent geometric figures and therefore provide meaningful contexts for mathematics learning. Integrating these cultural elements enables students to understand geometry not only as abstract knowledge but also as part of their local cultural environment.

The concept analysis also examined how each mathematical concept could be represented using Augmented Reality technology. Interactive visualization allows students to observe geometric figures from different perspectives, identify their characteristics, and connect mathematical properties with real cultural objects. Consequently, the integration of conceptual analysis and ethnomathematics serves as the foundation for designing learning activities that are interactive, contextual, and meaningful.

**Table 6**. Concept Analysis and Ethnomathematics Context

| Geometry Concept | Main Concepts | Cultural Context | Mathematical Connection |
|---|---|---|---|
| Square | Equal sides, right angles, perimeter, area | Window panels of Lawang Sewu | Properties of squares and area calculation |
| Rectangle | Opposite sides equal, perimeter, area | Facade walls of Lawang Sewu | Perimeter and area relationships |
| Triangle | Types of triangles, perimeter, area | Rooftop ornament of Gereja Blenduk | Triangle classification and area |
| Circle | Radius, diameter, circumference, area | Base pattern of Tugu Muda | Circle measurements and applications |

Table 6 demonstrates that every geometry concept has meaningful representations within Indonesian cultural buildings. These findings support the integration of ethnomathematics into geometry learning while providing authentic contexts for Problem Based Learning activities.

### 3.4 ETMAR Conceptual Prototype Design

The findings from the needs analysis, curriculum analysis, and concept analysis were synthesized to develop the conceptual prototype named ETMAR (Ethnomathematics Augmented Reality). The prototype was designed as an web-based learning media prototype accessible on laptops and mobile devices integrating interactive Augmented Reality visualization, Problem Based Learning, and ethnomathematics into a single learning environment. Rather than functioning merely as a visualization tool, ETMAR was designed to facilitate conceptual understanding through contextual exploration and collaborative problem solving.

The learning process begins with a contextual problem related to Indonesian cultural buildings representing geometric figures. Students subsequently use the AR feature to observe and explore three-dimensional representations of these buildings, identify the embedded geometric concepts, discuss solutions collaboratively, and reflect on the mathematical concepts learned. Through this sequence, students are expected to construct conceptual understanding while simultaneously developing problem-solving and communication skills.

The prototype also incorporates intuitive navigation and immediate feedback to support independent learning. These features enable students to interact with learning materials more actively than when using conventional textbooks or worksheets. Although the prototype has not yet been implemented in classrooms, its conceptual design provides a comprehensive framework for future application development and evaluation.

Based on the synthesis of findings from the needs analysis, curriculum analysis, and concept analysis, the ETMAR (Ethnomathematics Augmented Reality) conceptual prototype was designed with the following specifications. Product Identity:

- •Name: ETMAR (Ethnomathematics Augmented Reality)
- •Target Users: Grade V Elementary School Students (age 10–11)
- •Content: Plane Geometry (Square, Rectangle, Triangle, Circle)
- •Platform: Web-based, accessible on laptops and mobile devices (AR feature available on mobile)

**Table 7**. Main Features of the ETMAR Conceptual Prototype

| Feature | Description | Educational Purpose |
|---|---|---|
| AR Visualization | Interactive visualization of geometric figures embedded in cultural buildings | Improve conceptual understanding |
| Ethnomathematics Context | Indonesian cultural objects representing geometry concepts | Increase contextual relevance |
| Problem Based Learning | Authentic problem scenarios | Develop critical thinking and problem-solving skills |
| Interactive Activities | Observation, discussion, exploration, | Encourage active learning |

| |
|---|
| and reflection |

The integration of these features reflects the findings obtained from the previous analyses. Interactive visualization addresses students' difficulties in understanding geometry, contextual problems support meaningful learning experiences, and ethnomathematics connects mathematical concepts with students' cultural backgrounds. Therefore, the ETMAR conceptual prototype provides a theoretical basis for future research involving application development, expert validation, and classroom implementation.

**3D Object Development Process**

The 3D cultural building objects within ETMAR were designed using Tinkercad for 3D modelling and Assemblr for AR integration, following a three-stage modelling pipeline:

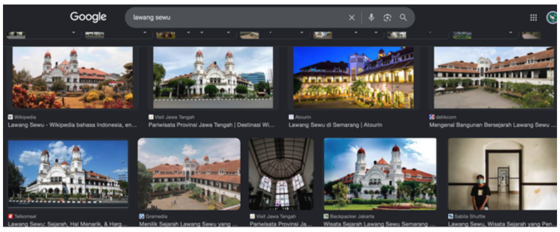


**Figure** 1. Reference image of Lawang Sewu as geometric context

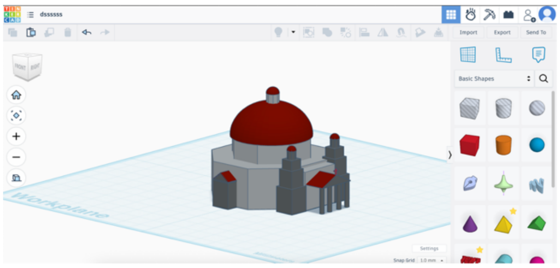

**Figure** 2. 3D modelling stage in Tinkercad

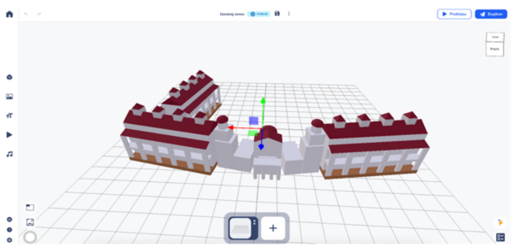

**Figure** 3. Final 3D result in Assemblr

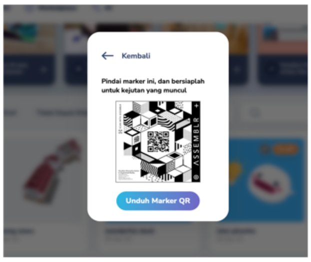


**Figure** 4. AR marker integration

**AR Interface Design**

The ETMAR application interface was designed to be intuitive and accessible for Grade V elementary school students. The main screens include a home menu, shape selector, AR camera view, and problem scenario display. The web-based AR interface design is presented in Figure 5 – 8.


**Figure** 5. Home screen


**Figure** 6. Map selection menu

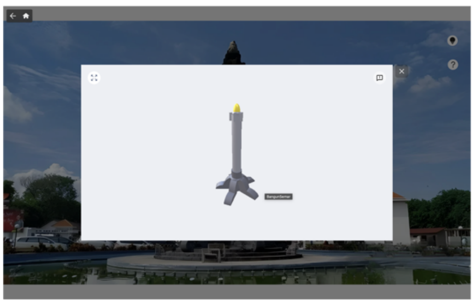

**Figure** 7. 3D in the media

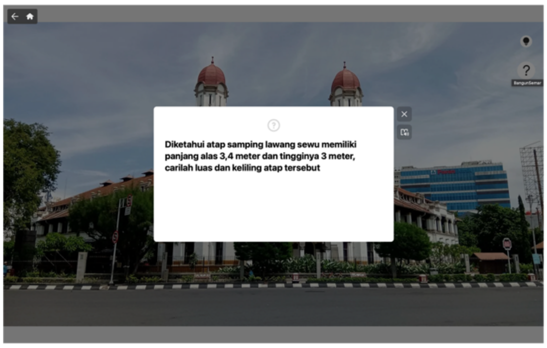


**Figure** 8. Problem scenario screen

**AR Output Example**

When students point their device camera at the provided marker, a 3D model of the relevant local cultural building appears overlaid on the real-world environment. An example of the AR output showing a 3D model of a Lawang Sewu overlaid on a physical marker is presented in Figure 9.

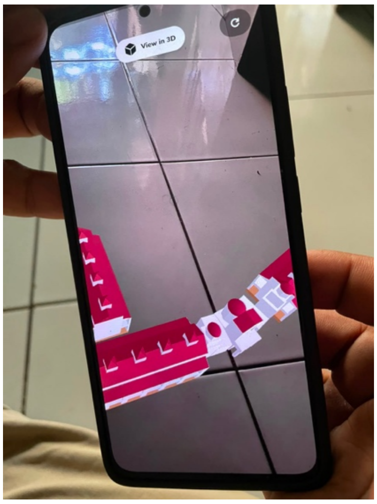


**Figure** 9. Example AR Output of ETMAR

**ETMAR Learning Flow:**

The learning experience within ETMAR follows a five-stage PBL-based flow:

1) Problem Orientation
The application presents a contextual problem grounded in a Semarang historical landmark. Three problem scenarios are available based on geometric shapes:
   - Lawang Sewu (Rectangle): "The front facade of Lawang Sewu has a rectangular window with a width of 120 cm and a height of 200 cm. What is the perimeter and area of the window?"
   - Tugu Muda (Circle): "The base of Tugu Muda monument has a circular pattern with a diameter of 8 m. What is the circumference and area of the base?"
   - Gereja Blenduk (Triangle): "The rooftop ornament of Gereja Blenduk forms an equilateral triangle with a side length of 3 m. What is the perimeter and area of the ornament?"
2) AR Exploration
The student scans the provided marker using their device camera. A virtual representation of the relevant Semarang landmark appears on screen. The student observes the shape embedded in the landmark, identifies its geometric properties and measurements, to gather information needed to solve the problem.
3) Group Discussion
Students work collaboratively to identify the geometric shape embedded in the landmark, determine its relevant measurements from the AR visualization, and formulate a solution strategy.
4) Solution Presentation
Each group presents their problem-solving process and answer. The application provides a structured space for students to input and explain their solutions.
5) Reflection and Concept Reinforcement
The application provides feedback on the solution and presents a concise summary of the relevant geometric concepts (properties of the shape, perimeter formula, area formula), consolidating students' understanding before proceeding to the next landmark.

This five-stage flow directly addresses all three findings from the needs analysis: the AR exploration stage resolves students' difficulties in visualizing plane geometric figures; the PBL structure develops problem-solving skills; and the cultural building context provides the meaningful, relevant learning experience that conventional media fails to deliver.

## CONCLUSION

This study produced a conceptual prototype design of mathematics learning media named ETMAR (Ethnomathematics Augmented Reality) for Grade V elementary school students on plane geometry content, grounded in systematic needs analysis, curriculum analysis, and concept analysis conducted through a qualitative descriptive design study approach.

The needs analysis confirmed that elementary school students face significant difficulties in recognizing and understanding plane geometric figures, and that existing learning media has not adequately addressed these challenges through interactive and contextual approaches. The curriculum analysis established that the Grade V plane geometry learning outcomes emphasizing conceptual understanding, contextual problem solving, and real-world application are highly compatible with the AR-PBL-ethnomathematics approach. The concept analysis validated that all four plane geometry shapes introduced at the elementary level (square, rectangle, triangle, and circle) have meaningful counterparts in Indonesian cultural objects and historical landmarks, particularly the iconic buildings of Semarang City, which provide rich and authentic ethnomathematics contextualization.

The resulting ETMAR prototype integrates AR-based interactive visualization of local cultural landmarks and buildings representing plane geometry concepts, PBL-structured contextual problem scenarios grounded in the historical buildings of Semarang (Lawang Sewu, Tugu Muda, and Gereja Blenduk), and a five-stage interactive learning flow on web-based platform accessible on both laptops and mobile devices. Each design decision in the prototype is directly justified by the findings of the three analysis stages, ensuring that ETMAR addresses real learning needs in a curriculum-aligned and culturally responsive manner. As a conceptual prototype, ETMAR has not yet been implemented or validated in classroom settings. Subsequent research should therefore proceed with application development, expert validation by mathematics education and instructional media specialists, and field trials to evaluate the validity, practicality, and effectiveness of the prototype in improving Grade V students' plane geometry learning outcomes. This study is expected to serve as a theoretically grounded foundation for future developmental work, contributing to the development of innovative, technology-enhanced, and culturally responsive mathematics learning media for Indonesian elementary schools.

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