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Needs Analysis and Hypothetical Learning Trajectory for Plane Geometry Through Obor Sewu Batik Ethnomathematics in Grade Iv

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Abstract

Elementary students may recognize familiar plane figures yet have difficulty describing defining properties and identifying the same figures in unfamiliar orientations. This study reports the preliminary design stage of Educational Design Research and aims to formulate a Hypothetical Learning Trajectory (HLT) for plane geometry using Obor Sewu batik as an ethnomathematical context to support Grade IV students' spatial reasoning. The qualitative evidence comprised classroom observation in a Grade IV class at SD Negeri Mayangkawis II, Bojonegoro, a semi-structured interview with the classroom teacher, analysis of Phase B geometry learning outcomes in the Kurikulum Merdeka, and a theoretical review of deep learning, ethnomathematics, Van Hiele's geometric thinking, and spatial ability. Observation and interview evidence were compared with curriculum expectations and theoretical constructs through thematic analysis; the resulting learning needs were then mapped onto Simon's components of learning goals, learning activities, and conjectures of students' thinking. The preliminary findings indicate that students' responses were dominated by visual recognition, including difficulty identifying familiar figures after rotation and explaining defining properties. Instruction was also reported to rely mainly on two-dimensional textbook and whiteboard representations. Analysis of the Obor Sewu motif identified five visually approximated geometric elements associated with triangles and quadrilaterals. These findings informed a five-stage proposed HLT: cultural orientation, motif exploration, mathematical formalization, collaborative problem solving, and reflection-transfer. The HLT is a preliminary instructional design rather than evidence of effectiveness; it requires expert review and classroom implementation in subsequent design-research phases.

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Keywords: deep learning, ethnomathematics, Obor Sewu batik, Hypothetical Learning Trajectory, spatial ability.

1. Introduction

Geometry is a central component of elementary mathematics, developing students' logical, spatial, and problem-solving abilities. Among grade IV geometry topics, plane figures require students not only to name shapes but to understand their properties sides, angles, and relationships between shapes. Spatial ability, the capacity to understand, manipulate, and represent shapes and spatial relationships mentally, is a key predictor of success in this domain (Hawes & Ansari, 2020; Mix & Cheng, 2012; Uttal et al., 2013).

Preliminary classroom observation of grade IV students at SD Negeri Mayangkawis II found that most students remained at Van Hiele's Visualization level (Level 0): when presented with a square rotated to an unfamiliar orientation, several students identified it as a kite or rhombus rather than a square, and students could not yet explain that a rectangle has two pairs of equal, parallel sides, or that a square is a special case of a rectangle. This condition indicates that students' geometric understanding is still dominated by visual perception rather than analytical reasoning, a problem linked to instruction that relies heavily on two-dimensional textbook images and lecture-based delivery with minimal concrete visualization.

Deep learning offers a relevant pedagogical response, positioning the teacher as a facilitator of meaningful, contextual learning experiences in which students construct understanding through active engagement with real problems (Fullan et al., 2018). In the Indonesian context this is operationalized through the Kerangka Pembelajaran Mendalam, integrating knowledge, skills, and character through experiences that are mindful, meaningful, and joyful (Indonesia, 2025). Ethnomathematics complements this approach by connecting abstract mathematical concepts to local cultural products (D'Ambrosio, 1985; Rosa & Orey, 2011). Bojonegoro's Batik Obor Sewu a motif rooted in the philosophy of the Sedulur Sikep/Samin community, symbolizing honesty, patience, and light contains repeated geometric forms: triangles in the kobaran api (flame) and tumpal, a rectangle in the batang obor (torch shaft), a parallelogram in the daun obor (torch leaf), and a square in the isen-isen (filler ornament). Its close ties to local identity make it a promising, culturally meaningful context for geometry instruction, yet this potential has not been optimally utilized in mathematics classrooms.

Previous ethnomathematics studies have demonstrated that cultural artifacts can reveal meaningful geometric ideas and serve as contextual resources for mathematics learning (Ana & Mariana, 2022; Diva Aftina Ardiyanti & Putri Nur Malasari, 2024; Marhummah & Mariana, 2020; Ulum, 2018). More recent work has also begun to translate ethnomathematical contexts into explicit learning trajectories rather than stopping at concept identification (Nurrahmawati et al., 2026; Nursyahidah et al., 2025). Building on this development, the contribution of the present study is to connect documented Grade IV classroom learning needs with the local context of Obor Sewu batik and to use those needs as the basis for a preliminary HLT for plane geometry. Accordingly,

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this article aims to describe (1) the current characteristics and challenges of Grade IV plane-geometry instruction in the observed setting and (2) a preliminary HLT, grounded in the needs analysis and relevant theory, intended to support students' reasoning about plane-figure properties and spatial orientation. The proposed HLT is not presented as evidence of learning effectiveness; its validity, practicality, and effectiveness remain to be examined in subsequent design-research phases.

2. Methods

This study reports the preliminary design stage of Educational Design Research (EDR), positioned as an initial investigation that precedes prototyping, classroom implementation, and assessment (Plomp & Nieveen, 2013). The purpose of this stage was not to test an intervention, but to identify learning needs and translate them into a theoretically informed HLT. The field-based evidence came from a Grade IV classroom at SD Negeri Mayangkawis II, Kecamatan Balen, Kabupaten Bojonegoro, and from the classroom teacher. Classroom observation focused on students' responses when identifying and describing plane figures in standard and rotated orientations and on the representations and instructional strategies used during geometry learning. A semi-structured teacher interview explored perceived student difficulties, student characteristics relevant to geometry learning, and current instructional practices. Curriculum analysis focused on Phase B geometry learning outcomes in the Kurikulum Merdeka, particularly competencies related to recognizing, describing, comparing, and reasoning about plane figures. Because the source draft contains only preliminary observation and interview records, it does not provide sufficient documentation to report participant counts, observation frequency and duration, interview duration, recording procedures, or formal ethics-approval details. These procedural details should be documented in the final research record before publication. The present analysis therefore treats the field evidence as context-specific preliminary evidence and does not claim representativeness.

In parallel, a theoretical review was conducted on deep learning, ethnomathematics, Van Hiele's theory of geometric thinking (Van Hiele, 1986), spatial ability, and learning-trajectory design. Analysis proceeded in three linked steps. First, observation and teacher-interview records were organized around recurring learning difficulties and instructional conditions, such as orientation-dependent shape recognition, difficulty articulating defining properties, and reliance on two-dimensional representations. Second, these themes were compared with Phase B curriculum expectations and interpreted using the theoretical constructs above. Third, the identified needs were translated into HLT components following (Simon, 1995)framework: learning goals, learning activities, and conjectures of students' thinking. Triangulation was used at the level permitted by the preliminary dataset by comparing classroom observations, teacher accounts, curriculum expectations, and theoretical literature. Claims about specific student responses are therefore interpreted as preliminary classroom evidence rather than as generalized findings. The resulting HLT is a design conjecture to be reviewed by experts and compared with students' actual learning trajectory during subsequent EDR prototyping and assessment (Gravemeijer, 2004; Gravemeijer & Cobb, 2006)

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3. Result and Discussion

Current Condition of Plane Geometry Instruction

Observation and interview results show that grade IV students' understanding of plane figures remains dominated by visual recognition rather than analytical reasoning. Students can generally name common shapes (triangle, square, rectangle) when presented in a standard orientation, but many fail to recognize the same shape when rotated for example, identifying a rotated square as a kite or rhombus. Students also struggle to explain relational properties, such as why a rectangle has two pairs of equal, parallel sides, or why a square is a special case of a rectangle.

Interviews with the classroom teacher revealed that instruction has relied mainly on two-dimensional illustrations from textbooks and the whiteboard, with limited use of concrete manipulatives or cultural context, and that repetition is the main strategy used to reinforce students' understanding of shape names. These findings indicate that students' geometric thinking is still positioned at Van Hiele's Visualization level (Level 0) and has not yet progressed toward the Analysis level (Level 1), where students identify and reason about shape properties. This finding is consistent with the view that spatial visualization, relation, and orientation together predict success in geometric reasoning (Hawes & Ansari, 2020; Mix & Cheng, 2012)

Geometric Elements Identified in the Obor Sewu Batik Motif

To address the identified learning gap contextually, the Obor Sewu batik motif, a cultural product associated with Bojonegoro and described as carrying values of honesty, patience, and light, was examined for visually identifiable plane-geometry features. The classification in Table 1 should be understood as a mathematical abstraction of decorative forms rather than a claim that every motif component is an exact Euclidean figure. Five motif elements were selected because their dominant outlines can be approximated by figures relevant to Phase B geometry: kobaran api and tumpal by triangles, batang obor by a rectangle, daun obor by a parallelogram, and isen-isen by a square. Classification was based on defining properties after simplifying decorative details: number of sides, relative side lengths, parallelism, and angle type. Scale, rotation, line thickness, curvature, and ornamentation may visually distort these properties; therefore, students are expected to trace or isolate the dominant boundary before classifying a figure. This distinction is pedagogically important because a rotated square remains a square, and a rectangle and a non-rectangular parallelogram must be distinguished by defining properties rather than by visual resemblance alone. Ethnomathematical studies demonstrate the value of explicitly mapping cultural objects onto geometric concepts, while remaining attentive to their mathematical properties (Diva Aftina Ardiyanti & Putri Nur Malasari, 2024; Putri Nur'aini et al., 2026). A labeled image of the original Obor Sewu motif should accompany Table 1 in the final manuscript; however, no publishable source image or reproduction permission was included in the submitted file, so an image has not been fabricated or inserted in this revision.

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Table 1. *Geometric Construction Analysis of the Obor Sewu Batik Motif*

Motif Element	Plane Figure	Group
 **Kobaran api** (*flame*)	Triangle	Triangle
 **Batang obor** (*torch shaft*)	Rectangle	Quadrilateral
 **Daun obor** (*torch leaf*)	Parallelogram	Quadrilateral
 **Isen-isen** (*filler ornament*)	Square	Quadrilateral
 **Tumpal**	Triangle	Triangle

Hypothetical Learning Trajectory (HLT) Design

Based on the needs analysis and theoretical review, a five-stage HLT was formulated as a preliminary design conjecture intended to support movement from appearance-based recognition toward property-based reasoning while engaging spatial visualization, spatial relation, and spatial orientation (Mix & Cheng, 2012; Uttal et al., 2013). The stages combine Van Hiele's phases of geometric thinking (Van Hiele, 1986) with (Simon, 1995)framework of learning objectives, activities, and conjectures, together with deep-learning and ethnomathematical principles. The design also responds to recent learning-trajectory research showing the importance of moving from contextual cultural representations toward formal geometric reasoning (Nurrahmawati et al., 2026; Nursyahidah et al., 2025, 2026). In particular, the exploration and formalization stages require students to verify figures using defining properties: parallel sides, equal side lengths where relevant, and right angles. Thus, a rectangle is not identified merely because it 'looks rectangular,' and a parallelogram is distinguished by its parallel opposite sides while angle properties are checked explicitly. The HLT remains hypothetical at this stage and requires expert validation and classroom testing.

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Table 2. *Hypothetical Learning Trajectory (HLT): Plane Geometry through Obor Sewu Batik*

Activity (Van Hiele Phase & Simon's Framework)	Learning Objectives	Activity Description	Students' Thought Conjecture
1. Cultural Orientation (Information)	Students can recognize visual patterns in Batik Obor Sewu and relate them to their cultural meaning.	Students observe an enlarged image/cloth of Batik Obor Sewu and discuss its origin and philosophical meaning (honesty, patience, light) with the teacher.	Students notice that the motif is built from repeated shapes; some spontaneously mention "kotak-kotak" or "segitiga" based on overall appearance, consistent with Van Hiele Level 0.
2. Motif Exploration (Guided Orientation)	Students can identify plane figures within the batik motif and recognize them in varied orientations.	Using coded motif cards (A–E), students trace and mark the outlines of shapes found in the kobaran api, batang obor, daun obor, isen-isen, and tumpal elements, then match each traced shape to a shape card.	Students initially misidentify the rotated isen-isen square as a rhombus or kite; guided questioning prompts them to test the shape's identity independent of orientation.
3. Mathematical Formalization (Explicitation)	Students can describe the properties (sides, angles) of each plane figure using correct mathematical terms.	In small groups, students count sides and corners of each traced shape, measure side lengths, and complete an LKPD stating properties.	Students begin to explain why the batang obor is a rectangle and why isen-isen is a square; some confuse rectangle and parallelogram until prompted to check angle size, indicating movement toward Van Hiele Level 1.
4. Collaborative Problem Solving (Free Orientation)	Students can compare, classify, and explain relationships between plane figures, including symmetry and repeated patterns.	Groups complete a batik-based worksheet: classifying traced shapes, finding lines of symmetry, and explaining why two shapes belong to the same or different groups.	Students are expected to justify classification using properties rather than appearance and to locate symmetry lines by folding motif cutouts, showing development in spatial relation and visualization.

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Activity (Van Hiele Phase & Simon's Framework)	Learning Objectives	Activity Description	Students' Thought Conjecture
5. Reflection and Transfer (Integration)	Students can transfer their understanding of plane-figure properties to create and explain a new pattern.	Each student designs a simple original batik-inspired pattern using at least three learned plane figures, then presents and explains the properties of the shapes used.	Students are expected to connect their new designs to previously discussed properties, spontaneously using terms like “sisi sejajar” or “sudut siku-siku” to justify their design.

The needs analysis indicates a gap between students’ visual recognition of familiar figures and the property-based reasoning expected in geometry learning. This finding supports the use of ethnomathematics as a bridge from culturally meaningful representations to formal mathematical ideas (Rosa & Orey, 2016). The five-stage HLT operationalizes this bridge by beginning with the cultural motif, isolating and tracing geometric forms, formalizing their defining properties, comparing and classifying them collaboratively, and finally transferring the concepts into a new design. This progression is consistent with recent elementary-geometry literature emphasizing culturally contextualized learning and systematic movement from concrete or contextual representations toward formal geometry (Istiningsih et al., 2026; Rifqa et al., 2026). Importantly, the proposed sequence should be interpreted as a design hypothesis rather than a demonstrated learning pathway.

Piaget, (1970)concept of assimilation and accommodation is visible in Stages 1–2, where students assimilate familiar motif shapes into existing schema and accommodate new understanding when a shape appears in an unfamiliar orientation directly addressing the difficulty observed in the preliminary study. Vygotsky's (1978) notion of cultural tools and the Zone of Proximal Development underlies the collaborative, teacher-scaffolded activities of Stages 3–4, while Ausubel, (1968) advance organizer concept explains why the batik motif, already familiar to students, is expected to strengthen the durability of newly formed concepts.

The contribution of this preliminary study lies in linking a context-specific needs analysis to an explicit HLT grounded in Obor Sewu batik, rather than making an absolute claim that comparable designs do not exist. Earlier studies have explored geometric concepts in cultural artifacts (Ana & Mariana, 2022; Diva Aftina Ardiyanti & Putri Nur Malasari, 2024; Marhummah & Mariana, 2020; Ulum, 2018) while recent studies have increasingly developed ethnomathematics-based learning trajectories for geometry (Nurrahmawati et al., 2026; Nursyahidah et al., 2025, 2026). Within that developing literature, the present HLT is specifically derived from the classroom difficulties documented in the preliminary study and organized using Simon’s (1995) relationship among learning goals, activities, and conjectured student thinking. The

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study has important limitations: the available preliminary records do not provide complete procedural metadata on participant numbers, observation and interview duration, or formal ethics documentation, and the HLT has not yet undergone expert validation or classroom implementation. Consequently, no claims are made regarding validity, practicality, or effectiveness. These aspects should be established during subsequent prototyping and assessment, when the hypothetical trajectory can be compared with students' actual learning trajectory and revised accordingly (Gravemeijer & Cobb, 2006).

4. Conclusion

This preliminary EDR study identified a context-specific need to move Grade IV plane-geometry learning from appearance-based recognition toward reasoning with defining properties, particularly when figures are presented in unfamiliar orientations. Drawing on classroom observation, a teacher interview, curriculum analysis, and relevant theory, the study formulated a five-stage HLT using Obor Sewu batik as an ethnomathematical context: cultural orientation, motif exploration, mathematical formalization, collaborative problem solving, and reflection-transfer. The proposed trajectory explicitly emphasizes verifying triangles and quadrilaterals through mathematical properties rather than visual resemblance and treats the geometric forms in the motif as instructional abstractions of decorative shapes. The HLT should be regarded as a preliminary design conjecture, not evidence of effectiveness. Its next development steps are expert review, classroom implementation, comparison of the hypothetical and actual learning trajectories, and iterative revision. The limited procedural detail available in the preliminary field records also restricts the generalizability of the present findings and should be addressed through more complete documentation in the subsequent research phases.

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