

Development of an Ethnomathematics-Based Worksheet Integrating the Traditional *Engklek* Game to Enhance Elementary Students' Spatial Ability on Cuboid Nets

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Abstract. This study was motivated by the fact that mathematics learning in elementary schools is still largely procedural and memorization-oriented, causing students to struggle in understanding spatial concepts, particularly in the topic of cuboid nets. Spatial ability plays an essential role in supporting reasoning and geometric visualization. Integrating cultural contexts through ethnomathematics can serve as a solution to create meaningful and contextual learning. One relevant local culture is the traditional Engklek game, which contains geometric patterns, symmetry, and spatial movements related to the concept of cuboid nets. This study aimed to develop an ethnomathematics-based student worksheet integrating the Engklek game to improve elementary students' spatial ability. The research employed the Design and Development method using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). The results indicated that the developed worksheet was highly feasible and effective, achieving 90.8% from material and media experts and 95.8% from teaching practitioners. The Engklek-based worksheet effectively enhanced students' spatial visualization skills while fostering cultural awareness and appreciation of Indonesian heritage through meaningful and contextualized mathematics learning.

Keywords: Ethnomathematics, Student Worksheet, *Engklek* Game, Spatial Ability, Cuboid Nets

INTRODUCTION

Recent international assessments reveal persistent challenges in geometry education. The 2019 Trends in International Mathematics and Science Study (TIMSS) showed that Indonesian fourth-graders scored lowest in the geometry domain compared to other mathematical content areas, with only 23% reaching the intermediate benchmark in spatial reasoning tasks (Mullis, Martin, Foy, Kelly, & Fishbein, 2020). This performance gap becomes particularly pronounced when students encounter three-dimensional geometric concepts requiring spatial visualization, the ability to mentally manipulate, rotate, and transform geometric objects.

Geometry learning in elementary schools plays a vital role in developing students' spatial reasoning and mathematical literacy (Octaria & Rawani, 2025). Spatial ability, the capacity to mentally manipulate and visualize objects in two- and three-dimensional space is essential for understanding geometric concepts, particularly three-dimensional shapes and their nets (Lowrie et al., 2017). Research indicates that students with underdeveloped spatial abilities not only struggle with advanced mathematics but also face difficulties in STEM fields and everyday problem-solving tasks such as map reading, architectural design, and understanding technical diagrams (Gilligan, Flouri, & Farran, 2017; Wai, Lubinski, & Benbow, 2009; Mufliva, et al., 2024). However, mathematics instruction in many elementary classrooms remains largely procedural and focused on memorization rather than conceptual understanding (Mulyono & Hapizah, 2018).

In the Indonesian curriculum, the concept of cuboid nets is introduced in fifth-grade elementary school (Basic Competencies 3.5 and 4.5, Kurikulum Merdeka) (Kemendikbudristek, 2022). However, current instructional practices face several challenges when students encounter topics requiring spatial visualization, such as cuboid nets (Elfa, Ikrami, & Rahmat, 2024). Traditional instruction methods, while widely practiced due to their efficiency in covering curriculum content, may provide limited opportunities for hands-on exploration and experiential learning (Yao, 2023). This can make it difficult for students to connect abstract formulas with real spatial relationships.

Teacher interviews conducted during the preliminary study indicated that students often treat net construction as a memorization task, recalling patterns without understanding the spatial relationships between faces, edges, and vertices. When presented with non-standard net configurations, students frequently failed to recognize whether a given pattern could fold into a cuboid (Ng & Sinclair, 2015). Observations and discussions with educators indicate that students often need stronger foundational concepts, and the diversity in learning pace requires differentiated instructional approaches. While various instructional aids such as visual materials and digital media have been introduced in many classrooms, consistent implementation remains challenging due to resource constraints and time limitations. Additionally, geometry lessons could benefit from stronger connections to students' real-life contexts to make learning more meaningful and engaging.

Recent research consistently documents difficulties elementary students face in geometry learning. Fauzi (2020) found that students struggle with geometric concepts like perimeter and area due to weak conceptual foundations. Awaludin et al. (2021) noted that geometric ideas are abstract and challenging for elementary students in the concrete operational stage without hands-on experiences. Agustina (2020) highlighted that lessons move too quickly from concrete to abstract, limiting students' meaning construction. Zubaidah (2017) argued that problem-solving and spatial reasoning skills remain underdeveloped because learning rarely links to real-world situations.

These challenges call for instructional approaches grounded in embodied cognition theory, which posits that cognitive processes are deeply rooted in the body's interactions with the world (Shapiro, 2019). For spatial learning specifically, research demonstrates that physical movement and gesture significantly enhance spatial reasoning by creating sensorimotor representations that support mental visualization (Hodgkiss, Gilligan, Tolmie, Thomas, & Farran, 2018). When learners physically manipulate objects or move through spatial configurations, they develop stronger mental models that facilitate abstract geometric reasoning (Supli dan Yan, 2024). This theoretical foundation suggests that game-based learning involving bodily movement may be particularly effective for developing spatial abilities required for understanding three-dimensional geometry.

Ethnomathematics has emerged as a promising framework integrating cultural values into mathematics education. Rosa and Orey (2016) developed this concept, showing how cultural contexts make mathematics more relevant and meaningful. Recent Indonesian studies demonstrate its effectiveness, Primrose & Masamah (2025) successfully integrated batik patterns into geometry instruction, while Prahmana and D'Ambrosio (2020) showed that traditional games contain rich mathematical concepts that enhance understanding and promote cultural preservation.

Research on traditional games shows their potential for mathematics learning. Nur et al. (2020) found that game-based learning significantly improves student motivation and conceptual understanding. Specifically, studies on Engklek (traditional hopscotch) reveal embedded mathematical concepts including geometric shapes, symmetry, and spatial orientation

(Ma'rifah & Rahayu, 2025). However, research on using Engklek for three-dimensional geometric concepts like cuboid nets remains limited.

Among various Indonesian traditional games, Engklek (traditional hopscotch) presents unique characteristics particularly suited for developing spatial abilities related to cuboid nets. First, Engklek's playing field consists of rectangular and square compartments arranged in specific patterns that structurally resemble unfolded cuboid faces. Second, the game requires players to physically navigate through these compartments using hopping and jumping movements, creating embodied experiences of spatial relationships, adjacency, and orientation is the same conceptual elements needed to understand how two-dimensional nets transform into three-dimensional objects (Tanujaya, Prahmana, & Mumu, 2021). Third, Engklek gameplay involves planning movement sequences and mentally visualizing paths, exercises that parallel the mental rotation and spatial visualization required for net construction. (Bruce & Hawes, 2015). Fourth, unlike other traditional games such as *congklak* (board game) or *gobak sodor* (chase game), Engklek's grid-based spatial structure provides direct visual and kinesthetic analogies to geometric nets. This makes Engklek not merely a motivational tool but a pedagogically meaningful medium for developing spatial cognition (Risdiyanti & Prahmana, 2017),

The focus on cuboid nets rather than other three-dimensional shapes is pedagogically justified for several reasons. First, cuboids (rectangular prisms) are among the first three-dimensional shapes introduced in elementary curriculum and serve as foundational concepts for more complex polyhedra (Fujita, et al., 2020). Second, Cuboids, commonly found in students' daily environments such as boxes, books, and buildings, represent mathematical concepts that are directly related to real-life contexts (Safitri, et al., 2023).

While existing research establishes the potential of ethnomathematics and game-based learning, significant gaps remain. First, although traditional games have been used for basic arithmetic and two-dimensional geometry, their application for developing spatial ability in three-dimensional concepts, particularly cuboid nets, is underexplored. Second, systematic design and validation of culturally-integrated worksheets targeting spatial ability through traditional games remains limited. Third, Engklek's potential for teaching advanced geometric concepts, specifically the relationship between two-dimensional nets and three-dimensional shapes, has not been systematically investigated. Fourth, empirical evidence on how traditional game integration affects both cognitive and affective outcomes through multiple evaluation perspectives is scarce.

This study addresses these gaps by developing and validating an ethnomathematics-based student worksheet integrating Engklek into cuboid nets instruction. The novelty lies in: (1) connecting Engklek's spatial patterns specifically to cuboid nets concepts, (2) systematically scaffolding progression from physical game movement to mental visualization, (3) comprehensive validation through experts and practitioners, and (4) explicit focus on spatial ability as a measurable outcome. To the best of our knowledge, this represents the first systematic attempt to design instructional materials that explicitly bridge traditional game-based spatial experiences with formal three-dimensional geometric reasoning. This contributes to ethnomathematics pedagogy while providing practical, validated materials for enhancing elementary students' spatial ability through culturally meaningful learning experiences.

To address these various problems, a systematic and student-centered learning innovation is needed. One effective approach is ethnomathematics, which integrates cultural values and local traditions into mathematics learning. Through the use of the traditional game Engklek, geometry lessons become more engaging and meaningful for students. This approach helps bridge abstract mathematical concepts with students' everyday experiences, allowing them to understand geometry through play, movement, and cultural context. The main objective of this

study is to develop an ethnomathematics-based student worksheet that integrates the traditional Engklek game into the teaching of geometry for elementary school students. Specifically, this study aims to:

- 1) Design a valid Engklek-based student worksheet for teaching cuboid nets concepts to fifth-grade elementary students, validated by content experts, media specialists, and cultural practitioners (Akker, et al., 2013; Mufliva, 2023).
- 2) Develop learning activities that systematically scaffold students' progression from concrete Engklek gameplay to abstract visualization of cuboid nets (van de Pol, Volman, & Beishuizen, 2010).
- 3) Examine the potential effectiveness of the worksheet in enhancing students' spatial visualization abilities, particularly mental rotation and spatial orientation related to three-dimensional geometric concepts (Hawes, et al., 2017)
- 4) Investigate teachers' and students' perceptions regarding the practicality, engagement value, and cultural relevance of the Engklek-integrated learning materials (Prediger, Gravemeijer, & Confrey, 2015).

The main objective of this study is to develop an ethnomathematics-based student worksheet that integrates the traditional Engklek game into the teaching of geometry for elementary school students. This worksheet is intended to help students understand the concept of cuboid nets through engaging and culturally meaningful learning experiences that connect mathematical ideas with real-life and local cultural contexts.

Through this development, the study aims to achieve several outcomes. First, the Engklek-based worksheet is expected to serve as an effective learning tool that strengthens students' spatial abilities, particularly in visualizing and reasoning about three-dimensional shapes. Second, it is expected to foster greater student engagement and motivation in learning mathematics by presenting geometry through movement, play, and familiar cultural elements. Third, the worksheet is designed to provide teachers with a practical and innovative teaching resource that supports student-centered learning while promoting the preservation of Indonesian cultural heritage.

The significance of this study extends across multiple dimensions. Theoretically, it contributes to the ethnomathematics literature by demonstrating how indigenous games can be systematically integrated into formal geometry instruction, particularly for developing spatial cognition (Rosa, et al., 2016). It extends embodied cognition theory by providing empirical insights into how culturally embedded physical activities can facilitate abstract mathematical reasoning (Nathan & Walkington, 2017). Practically, the validated worksheet offers teachers a ready-to-use, culturally responsive instructional resource that addresses documented gaps in current geometry teaching materials (Thanheiser, et al., 2016). For students, the approach promises more engaging and meaningful learning experiences that honor their cultural heritage while developing critical spatial abilities (Arisetyawan, Suryadi, Herman, & Rahmat, 2014). For curriculum developers and policymakers, this study provides evidence-based models for integrating local wisdom into national curriculum implementation, supporting both mathematics achievement and cultural preservation goals (Laurens, et al., 2017). Finally, the validation framework and design principles developed in this study can serve as templates for creating ethnomathematics-based materials for other mathematical topics and cultural contexts. Ultimately, this study seeks to demonstrate that integrating ethnomathematics into geometry instruction can create meaningful, contextualized, and enjoyable learning experiences that enhance both conceptual understanding and cultural appreciation among elementary school students.

METHODOLOGY

This study employed a Design and Development (DnD) research method using the ADDIE

model (Analysis, Design, Development, Implementation, Evaluation). The ADDIE model is one of the systematic instructional design frameworks developed in a structured and programmed manner through a sequence of stages aimed at solving learning problems related to learning resources that align with students' needs and characteristics (Tegeh & Kirna, 2013). This model is visually illustrated in Figure 1.



Figure 1. The Stages of the ADDIE Model

The validation process was carried out by experts, namely subject matter experts, media experts, and learning experts who acted as validators in this study. A limited trial was conducted with two fifth-grade students at an elementary school in Bandung to observe their responses to the ethnomathematics-based student worksheet that was developed, as well as with a fifth-grade teacher who acted as the teaching practitioner. The data obtained from subject matter, media, and learning experts was quantitative, while the data from students was qualitative. The feasibility of the developed worksheet was assessed using the Likert scale by Arikunto (as cited in Puspita, Rustini, & Dewi, 2021), as presented in Table 1.

Table 1. Feasibility Criteria of the Student Worksheet and Percentage Range

Score in Percentage (%)	Feasibility Category
< 21%	Very Infeasible
21 – 40%	Infeasible
41 – 60%	Fairly Feasible
61 – 80%	Feasible
81 – 100%	Highly Feasible

RESULTS AND DISCUSSION

The researchers conducted observations and a preliminary study on the spatial abilities of fifth-grade elementary school students, as well as in-depth interviews with the homeroom teacher and two fifth-grade students. The results indicated that students had difficulty distinguishing between cube nets that can and cannot be formed. They tended to assume that all examples of cuboid nets were identical and could be assembled into a solid shape.

This spatial understanding barrier can be addressed through ethnomathematics-based learning by integrating the traditional engklek game using puzzle mat media in the classroom. The study subsequently developed a learning sequence aligned with the Learning Outcomes of the Mathematics subject, Geometry Element, Phase C (Grade 5), in accordance with BSKAP Regulation No. 46 of 2025. This sequence was further elaborated into Learning Objectives Flow (*Alur Tujuan Pembelajaran*) and specific learning indicators that reflect the characteristics of the Merdeka Curriculum. The researchers also developed a student worksheet that incorporates the engklek game and exercises related to cuboid nets

Following the stages of the ADDIE model, the research process began with the **Analyze** phase, which involved analyzing the learning outcomes outlined in the Kurikulum Merdeka. This analysis focused on the required competencies for students, particularly understanding the concepts of cuboids and their nets, as presented in **Table 2**. In the **Design** phase, the

researchers created a framework for the interactive media program, which included selecting the learning materials, designing the characters, and determining the evaluation components. The **Development** phase involved the creation of the interactive media using several digital applications to support the design process. During the **Implementation** phase, the prototype was tested with two fifth-grade students. The trial activity included demonstrating the product and collecting feedback through teacher and student response questionnaires. Finally, in the **Evaluation** phase, the results indicated that the developed product was feasible and suitable for use in classroom learning.

Table 2. Learning Outcomes and Objectives

Learning Outcomes	Learning Objectives
Students construct and decompose three-dimensional shapes (cubes, cuboids, and their combinations) and recognize spatial visualization (front, top, and side views); compare the characteristics among plane and solid figures; and determine locations on maps using a grid system.	Students analyze cuboid nets through Engklek game activities and correctly assemble a puzzle mat

This worksheet is designed to include several components, namely: (1) Cover; (2) Identity; (3) Worksheet Identity; (4) Instructions for completion, tools, and material; (5) Activity 1: Playing Engklek and how to play it; (6) Activity 2: Observe the shapes in the Engklek game; (7) Activity 3: Observe the cuboid nets; (8) Activity 4: Let's Read and Let's Discover; and (9) Let's Observe, as presented in **Table 3**.

Table 3. Elements and Activities

Elemen	Activity
Cover	Contains the title, author's name, study program, faculty, and university.
Student Identity	Includes columns for group name, group members, and class.
Worksheet Identity	Includes subject, class or phase, main topic, learning outcomes, and learning objectives.
Instructions for Use, Tools, and Materials	<ol style="list-style-type: none"> 1. Contains instructions for using the worksheet. 2. Lists the tools and materials needed for the learning activities.
Activity 1	<ol style="list-style-type: none"> 1. Student will play the Engklek game in groups 2. Contains an explanation of how to play Engklek
Activity 2	Students will observe the Engklek game and relate it to the concept of plane shapes, connecting it to everyday life.
Activity 3	Students will observe pictures of cuboid nets provided in the worksheet and check the boxes next to the correct cuboid net shapes.
Activity 4	<ol style="list-style-type: none"> 1. Students will read the provided dialogue. 2. Then, they will write down the characteristics of a cuboid based on their observations.
Let's Observe	Students will arrange and attach pieces according to the given pattern to form a cuboid net that corresponds to the correct three-dimensional shape.

Based on the elements or activities that have been designed, the Student Worksheet was then developed using various images and texts appropriate for elementary school students. The development results show that the worksheet has been well-structured as an interactive learning medium through the Engklek game in ethnomathematics-based instruction on cuboid geometry for elementary students. The results of this development can be seen in Figures.

Table 4. Identity Cover Student Worksheet

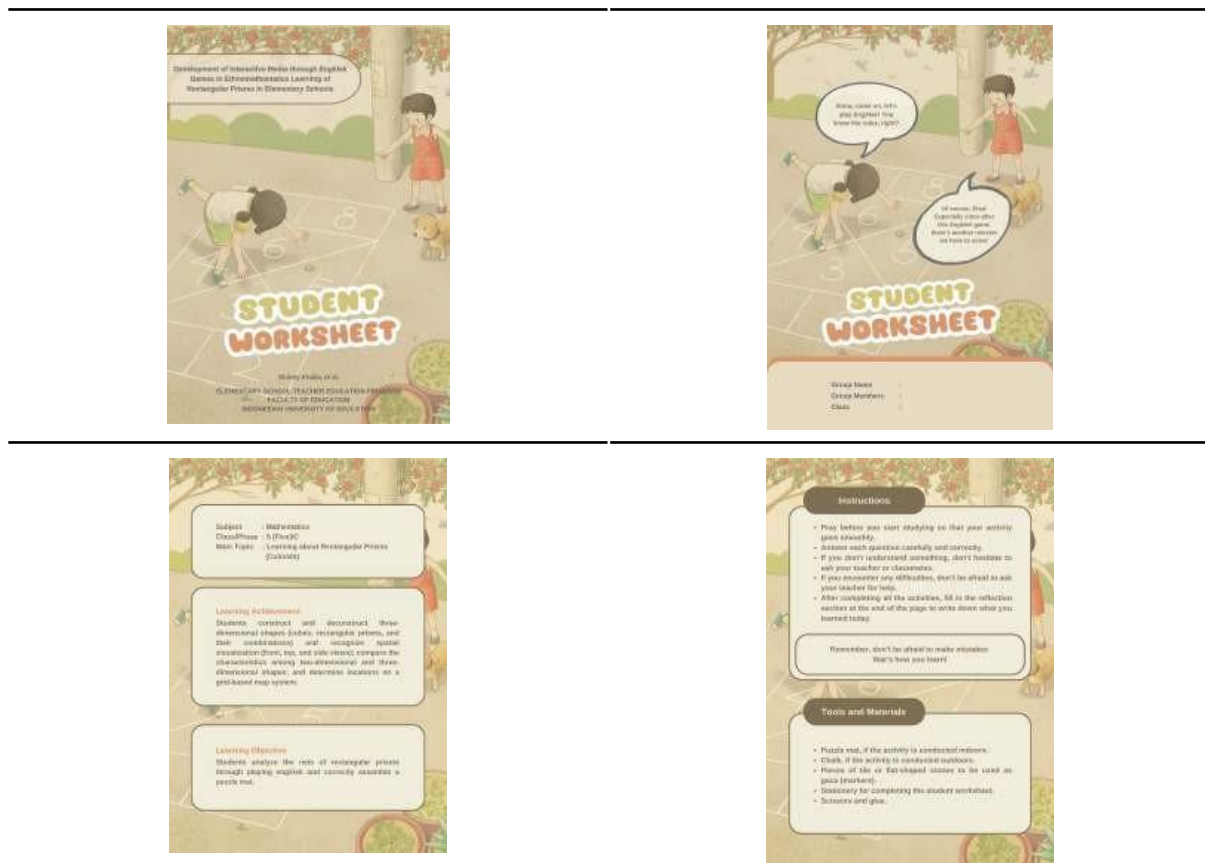


Table 4, illustrates the design layout of the student worksheet, which includes the student's identity section, learning outcomes, learning objectives, instructions for completion, as well as the tools and materials required for the engklek game.

Table 5. Steps in the Engklek Game



Table 5 describes the step-by-step procedures for playing the engklek game, which must be carried out in accordance with its sequential stages.

Table 6. Learning Activities in the Student Worksheet

Table 6 describes the students' learning activities while completing the student worksheet. The activities begin with identifying various plane shapes found in the engklek game pattern, followed by recognizing different types of cuboid nets and distinguishing those that do not form a cuboid. Finally, students are expected to identify

and describe the characteristics of a cuboid.

Table 7. Author's profile



Table 7 describes the profile introduction of the developer of the student worksheet. The worksheet was then validated by experts to ensure its quality and effectiveness before implementation. The validation process involved material experts, media experts, and learning experts. The validation results showed that the worksheet was categorized as highly feasible, as shown in Table 8.

Table 8. Expert Validation Results

Validation Aspect	Percentage	Category Material
Feasible	91,6%	Highly
Media	90%	Highly Feasible
Learning	91,8%	Highly Feasible
Average	91,1%	Highly Feasible

The validation results of the worksheet were categorized as highly feasible, as presented in Table 8 Based on these validation results, it can be concluded that the

worksheet is suitable for use as an interactive learning medium developed through the Engklek game in ethnomathematics-based learning of cuboid shapes in elementary schools. The implementation of the worksheet was carried out through a limited trial with students at one elementary school in the city of Bandung, and the results were categorized as highly feasible, as shown in Table 9.

Table 9. Descriptive Statistical Analysis Results

Results	Percentage	Category
Limited student trial	95,8%	Highly Feasible

Based on the results in the table, a percentage of 95.8% was obtained, which is categorized as highly feasible. This result indicates that the student worksheet is able to provide a positive contribution to improving the spatial abilities of elementary school students. The evaluation stage was carried out by taking into account the input from experts during the validation process. This feedback served as the basis for revising and refining the worksheet so that it becomes an effective learning medium.

This worksheet functions as a bridge between abstract mathematical concepts and the concrete experiences students encounter in their daily lives. The traditional Engklek game demonstrates that it contains mathematical concepts such as geometric shapes, symmetry, and spatial orientation (Ma'rifah & Rahayu, 2025). Through this strategy, students are not only memorizing formulas or procedures, but are also able to understand the deeper meaning behind geometric concepts. By involving elements of play, physical movement, and cultural contexts that are close to their lives, learning becomes more lively and enjoyable. This active interaction helps students connect mathematical ideas with real experiences, so that abstract thinking processes develop naturally through familiar activities. Ultimately, this approach strengthens students' conceptual understanding while also enhancing their appreciation of the cultural values embedded in the learning process.

CONCLUSION

Based on the results of research and discussion regarding the development of an ethnomathematics-based student worksheet that integrates the traditional game engklek in the topic of cuboid nets, it can be concluded that: (1) The ethnomathematics-based student worksheet integrating the engklek game is highly feasible for use, as indicated by the validation results from the material expert with a score of 91,6% and from the media expert with a score of 90%, resulting in an average score of 90,8% categorized as highly feasible. (2) The assessment from the learning expert obtained a score of 95,8%, also categorized as highly feasible. (3) Based on a limited trial conducted with fifth-grade students, the ethnomathematics-based student worksheet received a score of 95,8%, again categorized as highly feasible.

This ethnomathematics-based student worksheet is therefore considered highly suitable for helping students understand spatial concepts in the topic of cuboid nets. Moreover, as it is developed based on ethnomathematics by integrating cultural contexts through the engklek game, it makes learning more contextual and meaningful for students. Hence, it is expected that the developed student worksheet can serve as a medium for students to better understand the concept of cuboid nets, enhance their spatial visualization skills, and foster cultural appreciation by engaging in traditional Indonesian games that are enjoyable and encourage active participation in the learning process.

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