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Engklek as Ethnomathematics Learning Media: Reducing Elementary Students' Misconceptions of Geometry

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Abstract:
This research addresses fourth-grade students' low conceptual understanding and frequent misconceptions in data structures at SD Islam Bandar Kidul, alongside their strong preference for kinesthetic, play-based learning. To resolve these issues, an interactive ethnomathematics media based on traditional games was developed as an engaging alternative learning tool. The primary objective was to evaluate the development procedure, feasibility, effectiveness, and practicality of this ethnomathematics media in minimizing student misconceptions. Employing a Research and Development (R&D) design, the study followed the five-stage ADDIE model: Analysis, Design, Development, Implementation, and Evaluation. The research subjects comprised fourth-grade elementary students, divided into a small-group trial of 7 participants and a large-group trial of 20 participants. Data collection involved observation, interviews, diagnostic tests, and documentation. Data were subsequently analyzed using combined qualitative and quantitative descriptive methods to examine feasibility, practical utility, and learning gain metrics. Findings demonstrated that: (1) the media was successfully developed following all ADDIE phases; (2) expert validation confirmed high media feasibility, exceeding 80% and earning a "very feasible" rating; (3) the media effectively reduced misconceptions, achieving an N-Gain score of 0.7286, categorized as high effectiveness; and (4) educator and student response questionnaires yielded practicality scores of 96% and 81% respectively, establishing the traditional game-based ethnomathematics media as highly practical for classroom instruction.

Keywords: Ethnomathematics; Traditional Games; Engklek; Plane Shapes; Misconceptions; Research And Development

Introduction

Contemporary educational paradigms increasingly demand that learning processes establish robust, organic connections between individual cognitive development, societal frameworks, and cultural ecosystems, recognizing that education transcends mere information transmission to cultivate emotional intelligence, character integrity, and practical acumen grounded in authentic cultural contexts (Supriyanto, 2024). Within the Indonesian educational landscape, this philosophical imperative is codified under Law Number 20 of 2003 concerning the National Education System, which mandates that educational endeavours must be structured systematically to empower learners to actively develop their spiritual awareness, self-regulation, noble character, and essential intellectual capacities (Wahyudi & Hidayat, 2023). As the educational ecosystem transitions toward the *Kurikulum Merdeka* framework, primary school mathematics instruction is uniquely positioned to grant students the autonomy to explore cognitive frameworks by meaningfully bridging mathematical abstractions with tangible, real-world phenomena (Utami et al., 2024). Mastering foundational mathematics is imperative for nurturing logical reasoning, critical thinking, spatial awareness, and sound decision-making competencies among young learners (Prasetyo, 2025). Nevertheless, instructional barriers frequently emerge within primary classrooms, hindering conceptual mastery and engendering persistent learning difficulties (Rahmawati, 2024). As articulated in classical and contemporary educational psychology, these learning hurdles encompass complex challenges in sensory perception, linguistic expression, reading comprehension, writing proficiency, and mathematical cognition, which can severely impede a student's academic trajectory if left unaddressed (Kurniawan, 2023).

Empirical diagnostic observations conducted at SD Islam Bandar Kidul revealed critical instructional challenges within the fourth-grade mathematics classroom, particularly concerning the foundational domain of two-dimensional geometry (Annisa et al., 2025). Mathematics is frequently perceived by young primary students as an abstract, rigid, and burdensome discipline, leading to widespread cognitive disengagement, anxiety, and superficial rote memorization (Sari & Wijaya, 2023). Classroom diagnostic assessments indicated that over half of the student population—specifically 57 percent—possesses a predominant kinesthetics learning modality, exhibiting heightened academic engagement and cognitive retention when instructional activities incorporate experiential, play-based methodologies (Fauziyah, 2025). Conversely, conventional instructional practices have predominantly relied on direct lecturing, textbook-bound problem solving, and passive listening immediately following brief board explanations (Hidayatullah, 2024). Consequently, students struggle to grasp abstract geometric properties, resulting in pronounced and deep-seated cognitive misconceptions regarding shape attributes, angles, and boundary classifications (Lestari, 2024). Baseline pre-test evaluations underscored this predicament, yielding a low class average of 57.5, which was characterized by fundamental errors in defining and differentiating the structural attributes of basic plane shapes (Annisa, 2025).

To bridge the yawning gap between formal mathematical abstraction and concrete experiential realities, this research integrates the rich paradigm of ethnomathematics with traditional children's games, specifically leveraging the culturally rooted traditional game of *Engklek* (Setiawan, 2024). Grounded firmly in Jean Piaget's foundational theory of cognitive development, children aged nine to ten years old reside squarely within the concrete operational stage of cognitive growth (Piaget, 1972; Santrock, 2020). During this developmental window, children can reason logically about concrete events, manipulate physical objects, and classify items into distinct

categories based on observable attributes, yet they continue to experience substantial cognitive hurdles when confronting purely abstract textual formulations (Hurlock, 2021). Traditional games provide a culturally resonant, highly accessible medium that satisfies this developmental prerequisite, successfully transforming abstract geometric properties into tangible, kinesthetics learning experiences that resonate with the students' lived cultural environments (Zabeta et al., 2023). By embedding mathematical concepts into the familiar physical layout and dynamic rules of *Engklek*, students are afforded the opportunity to physically interact with geometric shapes, thereby internalizing structural properties through bodily movement and spatial manipulation (Kusuma, 2024).

Building upon these pedagogical imperatives, the overarching objective of this developmental research is to systematically construct, validate, and evaluate an innovative instructional intervention designed to transform geometry learning in primary schools (Plomp, 2013). Specifically, the study aims to formulate the systematic procedural design for developing traditional game-based ethnomathematics learning media addressing plane shape concepts for fourth-grade elementary students, ensuring a rigorous development cycle from initial conceptualization to final product realization (Annisa & Fauziyah, 2025). Furthermore, the study seeks to evaluate the expert-validated technical and content feasibility of the developed ethnomathematics media, ensuring its pedagogical soundness and safety in minimizing student misconceptions (Nieveen, 2019). Another core objective is to measure the empirical effectiveness of the instructional media in mitigating geometric misconceptions through rigorous pre-test and post-test experimental evaluations within a controlled classroom setting (Creswell, 2018). Finally, the research to determine the practical utility, user-friendliness, and operational efficiency of the learning media based on comprehensive educator and student response questionnaires, ensuring that the product is viable for widespread classroom adoption (Sugiyono, 2022).

To establish a rigorous theoretical foundation and prevent academic redundancy, this research systematically examines preceding scholarly investigations concerning ethnomathematics and geometry education. For instance, Lahagu et al. (2025) explored traditional *Baluse* culture relative to plane shape concepts, demonstrating that integrating local cultural wisdom into mathematics instruction significantly enhances student engagement and cultural preservation. Similarly, Lisnaini et al. (2020) investigated ethnomathematics through the architectural context of the Balaputera Dewa State Museum in South Sumatra, establishing that culturally contextualized environments facilitate students' comprehension of two-dimensional geometry. Extending this inquiry, Ratuanik and Filindity (2021) examined geometric concepts embedded within stone boat traditions in Tanimbar, emphasizing that ethnomathematical explorations effectively prevent persistent student misconceptions in geometry. Furthermore, Febriyanti et al. (2018) explored Sundanese traditional games such as *Engklek* and spinning tops, revealing that the spatial layout of *Engklek* intrinsically embodies geometric figures such as squares, rectangles, and semicircles, while simultaneously instilling collaborative character values. Complementing these historical and cultural studies, Hariani et al. (2024) and Solihin and Rahawati (2024) successfully developed digital and QR-based ethnomathematics learning media, demonstrating high validity, practicality, and effectiveness in primary mathematics instruction.

While preceding literature predominantly focuses on qualitative cultural explorations, architectural documentations, or purely digital media adaptations, this

study establishes distinct and significant academic novelties (Borg & Gall, 2003). First, unlike abstract theoretical explorations, this study physically transforms the spatial layout and mechanics of the traditional game *Engklek*—locally recognized as *Gejrik* in the Kediri context—into an interactive, offline, kinesthetics learning apparatus meticulously tailored for fourth-grade primary students (Annisa, 2025). Second, rather than assessing general academic achievement alone, the research specifically targets and evaluates the reduction of geometric misconceptions utilizing diagnostic *three-tier test* instruments, thereby moving beyond superficial grading metrics to isolate specific conceptual errors regarding shape attributes, side lengths, and angle classifications (Treagust, 1995; Kaltakci-Gurel et al., 2017). Third, the study implements a comprehensive and robust Research and Development (R&D) methodology utilizing the complete ADDIE model, supported by rigorous empirical testing including normality, homogeneity, Wilcoxon signed-rank, and N-Gain analyses to ensure empirical validity (Branch, 2009; Hake, 1999).

The instructional product developed through this rigorous research process is designated as Ethnomathematics Media Based on Traditional Games for Plane Shapes (Annisa, 2025). The physical and technical specifications of this educational product have been meticulously engineered to withstand active classroom use while maximizing pedagogical efficacy. The primary component of the product is the playmate structure, constructed from durable, waterproof banner material measuring 60 x 60 cm with a robust thickness of 2 cm, comprising 16 interconnected playmate units featuring detachable geometric cutouts that allow students to physically assemble and deconstruct shapes (Annisa & Fauziyah, 2025). Accompanying the playmate are specialized game tokens, locally known as *gaco*, fabricated from durable, eco-friendly plywood shaped into distinct geometric configurations and coated with protective laminate stickers to maximize visual appeal and tactile engagement during active play (Wibowo, 2024).

To facilitate cognitive reflection and assessment, the product incorporates interactive learning cards designed utilizing advanced digital graphic design platforms to produce distinct, color-coded card categories—including Question Cards, Answer Cards, Command Cards, and Geometric Characteristic Cards—which are securely housed within durable, labelled container boxes to ensure organizational longevity (Pratama, 2024). Crucially, the entire instructional package is supported by a comprehensive companion guidebook spanning 13 pages and formatted in a portable A5 size (Annisa, 2025). This guidebook incorporates thorough pedagogical introductions, alignment with institutional learning outcomes and competency profiles (CP/TP), historical overviews of the *Engklek* tradition, detailed technical product specifications, and explicit operational instructions for both educators and learners (Kemendikbudristek, 2022). Through the seamless integration of cultural heritage, kinesthetics engagement, diagnostic evaluation, and robust physical design, this development research offers a transformative contribution to primary mathematics education, effectively addressing cognitive misconceptions while fostering a renewed appreciation for indigenous cultural wisdom (Bishop, 1988; D'Ambrosio, 2001).

Methods

The methodological framework grounding this educational research and development inquiry is systematically structured upon the Research and Development (R&D) paradigm, specifically operationalizing the classic ADDIE instructional design model—comprising the sequential stages of Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009; Dick, Carey, & Carey, 2015). Situated within the context of primary mathematics education at SD Islam Bandar Kidul, this

developmental methodology is purposefully engineered to bridge the persistent gap between abstract theoretical frameworks and empirical classroom realities by creating, validating, and empirically testing interactive educational media (Annisa, 2025; Borg & Gall, 2003). By adhering to the systematic phases of the ADDIE framework, the research ensures that the resulting instructional product—specifically designed around traditional game-based ethnomathematics—meets stringent criteria for pedagogical validity, practical utility, and measurable impact on student cognitive misconceptions (Nieveen, 2019; Plomp, 2013).

The initial analytical phase of the research commenced with a comprehensive diagnostic needs assessment, student characteristic analysis, and curriculum alignment evaluation, establishing the empirical necessity for an instructional intervention (Branch, 2009). Front-end observations revealed pronounced conceptual bottlenecks in fourth-grade two-dimensional geometry, where conventional teacher-centered lectures failed to actively engage learners, resulting in widespread student misconceptions regarding shape attributes and geometric properties (Annisa et al., 2025). Concurrently, a student profile evaluation indicated that 57 percent of the target population possessed a dominant kinesthetics learning modality, necessitating experiential, movement-oriented learning environments to foster cognitive retention (Fauziyah, 2025). Furthermore, curriculum analysis synchronized the learning objectives with the mandated *Kurikulum Merdeka* framework, mapping specific competency goals (*CP* and *TP*) to concrete plane shapes (Kemendikbudristek, 2022). These foundational insights provided the theoretical justification for incorporating indigenous cultural elements into primary mathematics instruction (Bishop, 1988; D'Ambrosio, 2001).

Transitioning into the Design phase, the research focused on conceptualizing the architectural specifications, physical layout, operational mechanics, and evaluative instruments of the instructional media (Richey & Klein, 2007). The structural design specified an offline, kinesthetics playmate derived from the spatial layout of the traditional *Engklek* game (*Gejrik* in the local Kediri dialect), dimensioned at 60x60 cm with a thickness of 2 cm and partitioned into 16 modular units featuring detachable geometric cutouts (Annisa, 2025). Alongside the physical playmate, the design incorporated specialized game tokens (*gaco*) fabricated from laminated eco-friendly plywood, four color-coded interactive card categories (Question, Answer, Command, and Characteristic Cards), and a 13-page A5 companion guidebook (Pranata, 2024; Wibowo, 2024). Crucially, to systematically classify cognitive performance and identify underlying errors, the study formulated an indicator framework mapping geometric attributes to specific diagnostic targets and potential student misconceptions (Treagust, 1995; Kaltakci-Gurel et al., 2017).

Table 1. Misconception Indicator Matrix for Two-Dimensional Geometry

No	Geometric Sub-Topic	Diagnostic Indicator	Potential Student Misconception	Target Cognitive Domain
1	Square & Rectangle Attributes	Differentiating side-length relationships and interior angle properties	Assuming all four-sided polygons are squares regardless of side proportionality or right-angle orientation	Conceptual & Spatial Reasoning
2	Triangle Classification	Identifying properties of equilateral, isosceles, and scalene triangles	Believing a triangle is no longer a triangle if rotated away from a horizontal base orientation	Perceptual Misconception

3	Parallelogram & Trapezoid Features	Differentiating parallel sides from equal-length adjacent sides	Confusing opposite parallel boundaries with congruent side lengths across irregular quadrilaterals	Attribute Classification
4	Perimeter vs. Area	Distinguishing boundary length summation from internal surface coverage	Conflating perimeter with area formula by multiplying dimensions instead of adding boundary segments	Procedural Misconception

Alongside the indicator matrix, this phase included the structural formulation of diagnostic evaluation instruments—specifically a diagnostic *three-tier test* designed to systematically isolate and differentiate true scientific understanding from false positives, superficial guessing, and deep-seated geometric misconceptions (Treagust, 1995; Kaltakci-Gurel et al., 2017).

The structural design and decision-making framework of the diagnostic three-tier instrument is presented below:

Table 2. Decision Matrix for Diagnostic Three-Tier Test Classification

First Tier (Content Choice)	Second Tier (Reasoning Choice)	Third Tier (Confidence Level)	Cognitive Classification Category	Diagnostic Interpretation
Correct	Correct	Certain / High	Scientific Conception (Mastery)	Student possesses sound conceptual understanding
Correct	Incorrect	Certain / High	Misconception (False Positive)	Student holds a persistent misconception despite correct answer
Incorrect	Correct	Certain / High	Misconception (Reasoning Deficit)	Student uses faulty premises leading to incorrect conclusions
Incorrect	Incorrect	Certain / High	Misconception (Deep-Seated)	Student exhibits systematic and deep-seated conceptual error
Correct	Correct	Uncertain / Low	Lucky Guess	Student answers correctly without cognitive confidence
Incorrect	Any	Uncertain / Low	Lack of Knowledge	Student lacks underlying subject-matter knowledge

During the Development phase, the physical prototype of the *Engklek*-based ethnomathematics media was constructed and subjected to rigorous expert validation to establish content, media, and linguistic feasibility prior to field testing (Nieveen, 2019). The validation panel consisted of senior specialists in primary mathematics education, educational technology, and instructional linguistics who evaluated the prototype using standardized Likert-scale instruments (Sugiyono, 2022). Quantitative scores obtained from the validators were analyzed using percentage agreement criteria, yielding high validity indices that confirmed the product's conceptual safety, structural accuracy, and pedagogical alignment with elementary standards (Annisa & Fauziyah, 2025).

Constructive qualitative feedback from the expert panel was systematically utilized to refine the physical durability of the playmate, enhance the legibility of the instructional cards, and clarify the operational guidebook, producing a revised, field-ready prototype (Thiagarajan et al., 1974).

The Implementation phase operationalized the refined instructional media within a real-world classroom setting at SD Islam Bandar Kidul to evaluate its practical utility and empirical efficacy under active learning conditions (Creswell, 2018). Employing a pre-experimental one-group pretest-posttest design, baseline geometric understanding and pre-existing misconceptions were recorded prior to the instructional intervention (Campbell & Stanley, 1963). Students actively engaged with the *Engklek* media through structured kinesthetic movement, token placement, and collaborative card-based problem-solving designed to internalize plane shape attributes (Setiawan, 2024; Kusuma, 2024). Following the intervention, a post-test utilizing the validated diagnostic *three-tier test* was administered to quantify conceptual gains and measure the reduction of specific geometric misconceptions (Annisa, 2025). Practicality data were simultaneously gathered through structured response questionnaires distributed to both the classroom educator and participating students at the conclusion of the trial (Sugiyono, 2022).

In the final Evaluation phase, both formative and summative data analyses were executed to ascertain the ultimate validity, practicality, and effectiveness of the developed learning media (Branch, 2009). Quantitative pre-test and post-test scores underwent prerequisite statistical testing, including Shapiro-Wilk normality and homogeneity evaluations, to select appropriate analytical procedures (Field, 2013). To determine whether the reduction in student misconceptions and the elevation in academic performance were statistically significant, the non-parametric Wilcoxon signed-rank test was administered due to sample distribution characteristics (Conover, 1999). Furthermore, the magnitude of instructional gain was evaluated using Hake's Normalized Gain (N-gain) formula:

$$g = \frac{\%\, S_{post} - \%\, S_{pre}}{100 - \%\, S_{pre}}$$

where <g> represents the normalized gain score, $\%\, S_{post}$ denotes the average post-test percentage, and $\%\, S_{pre}$ indicates the average pre-test percentage, classifying the media's effectiveness into established low, medium, or high gain thresholds (Hake, 1999). Complementing these empirical metrics, user response data from teachers and students were analyzed to verify that the media achieved exceptional practical utility, operational ease, and student engagement.

Results and Discussion

Findings

The development of traditional game-based ethnomathematics media aims to address learning barriers and student misconceptions regarding plane shapes (bangun datar) among fourth-grade students at SD Islam Bandar Kidul. Based on preliminary observations and curriculum analysis, students predominantly exhibit a kinesthetic learning style and frequently encounter learning difficulties, reflected in a low average pretest score of 57.5. These misconceptions typically manifest when students struggle to accurately explain the definitions, attributes, and characteristics of various two-dimensional geometric figures. To resolve this gap between formal classroom mathematics and real-world cultural contexts, a Research and Development (R&D)

methodology adopting the ADDIE model was systematically implemented to design an interactive, contextual learning medium.

The procedural implementation of the development followed the five structured phases of the ADDIE instructional design framework, starting with comprehensive analysis, design, development, implementation, and evaluation. During the analysis phase, curriculum alignment with the Kurikulum Merdeka and student cognitive characteristics within Jean Piaget's concrete operational stage (ages 7–11) were examined, revealing an urgent need for concrete, culturally embedded learning tools. The design phase subsequently translated these pedagogical requirements into a physical playmate media layout measuring 60 cm × 60 cm with a thickness of 2 cm, featuring detachable geometric pieces, traditional hopscotch (engklek) movement tokens (gaco), question-and-answer cards, and an instructional guidebook developed via Canva. This structured developmental pathway ensured that every component of the product directly addressed the identified instructional constraints and learning objectives (Branch, 2009).

Product validation evaluated by multi-disciplinary experts demonstrated exceptional validity across media, material, assessment, instructional design, and questionnaire aspects. Media validators confirmed that the physical design, layout safety, and durability achieved an average score of 85%, classifying the medium as "very feasible" for classroom application. Furthermore, material experts rated the content accuracy, alignment with learning objectives (TP/CP), and language suitability at 93.7%, affirming that the mathematical concepts of plane shapes were rigorously presented. Assessment instruments, including three-tier diagnostic tests designed to isolate misconceptions, achieved average validity scores exceeding 95%, while instructional experts and questionnaire validators rated the module and response instruments between 92.5% and 98.7%. These rigorous expert appraisals established that the product met all necessary qualitative and quantitative benchmarks prior to empirical testing.

The empirical implementation of the ethnomathematics media was conducted in two distinct stages: a small-group trial involving 7 students and a large-group trial involving 20 fourth-grade students. Quantitative evaluation of student learning outcomes via pretest and posttest measurements demonstrated a substantial upward shift in academic performance. In the small-group trial, the average student score improved from a pretest baseline of 43 to a posttest average of 83, while the large-group trial exhibited an increase from an average pretest score of 38 to a posttest average of 84. Normality testing via the Shapiro-Wilk procedure indicated non-normal distribution for pretest data ($p = 0.013 < 0.05$), necessitating non-parametric analysis. Consequently, the Wilcoxon Signed-Ranks Test yielded an asymptotic significance value of $p < 0.001$, confirming a statistically significant difference and verifying that the traditional game-based media successfully enhanced student comprehension.

To precisely evaluate the pedagogical efficacy of the medium in mitigating student misconceptions, a three-tier diagnostic test structure was implemented to differentiate true conceptual understanding from guesswork or lack of knowledge. The analysis revealed a marked reduction in classification and theoretical misconceptions—such as the erroneous belief that all quadrilaterals are squares or that rhombuses contain right angles—following interaction with the ethnomathematics media. Furthermore, the calculation of the N-gain score across the trial cohorts produced a value of 0.7286, which falls squarely within the high effectiveness classification threshold ($0.70 \leq n \leq 1.00$). This high N-gain metric substantiates the quantitative finding that integrating traditional cultural games into primary mathematics instruction significantly optimizes conceptual retention and minimizes geometric misunderstandings among young learners.

The practical utility and operational feasibility of the developed media were assessed through educator and student response questionnaires administered upon completion of the implementation phase. The educator response questionnaire yielded an average practicality score of 96%, while the student response questionnaire achieved an average score of 81%, both comfortably placing the product within the "very practical" category of evaluation criteria. Qualitative feedback gathered during classroom observations and student interviews indicated that the kinesthetics nature of the traditional hopscotch activity fostered high engagement, reduced learning anxiety, and provided meaningful tactile representations of abstract geometric properties. These empirical findings collectively validate that the traditional game-based ethnomathematics medium is highly functional, efficient, and well-suited for regular classroom integration in primary mathematics education.

Analysis

Synthesizing research findings within the domain of educational development necessitates an analytical framework that rigorously bridges theoretical assumptions with empirical classroom realities derived from structured developmental iterations. Within the scope of evaluating instructional interventions grounded in ethnomathematics and traditional game integration, the interpretation of findings moves far beyond simple descriptive tabulations to capture the profound cognitive, behavioral, and structural shifts experienced by primary school students (Humairo, 2026). This analytical narrative examines the culmination of data gathered throughout the final implementation stages, establishing how structured instructional media successfully addresses learning barriers, minimizes geometric misconceptions, and enhances conceptual retention among young learners. The overarching goal of this final evaluation is to provide an exhaustive, scholarly account of the pedagogical outcomes, theoretical implications, and practical limitations encountered during the research process, thereby offering a reliable blueprint for future curriculum design and educational innovation.

The systematic execution of the research and development methodology followed the comprehensive five-phase ADDIE instructional design framework, ensuring that every operational step contributed directly to the pedagogical efficacy of the final product (Branch, 2009). During the initial analysis phase, careful empirical examination of curricular documents, student learning characteristics, and classroom observations at SD Islam Bandar Kidul revealed critical gaps in instructional delivery, specifically concerning abstract geometric concepts taught to fourth-grade students. The subsequent design phase translated these diagnostic insights into a concrete physical and digital prototype, incorporating specialized media layouts, instructional guidebooks, and Canva-designed elements tailored to developmental cognitive stages (Arikunto, 2021). Following expert validation, the implementation phase deployed the instructional media across controlled small-group and large-group trials, systematically tracking baseline pretest metrics and posttest outcomes to evaluate cognitive transformation and misconception reduction under realistic classroom constraints.

The rigorous evaluation of product feasibility conducted by multi-disciplinary experts demonstrated exceptional validity across media engineering, material content, assessment design, and instructional usability aspects (Van den Akker, 1999). Expert validators in media design and subject-matter content awarded high percentage scores ranging from 88.8% to 100%, consistently classifying the traditional game-based ethnomathematics media within the highest tier of qualitative feasibility. Specifically, content validators confirmed that the mathematical attributes of plane shapes were

rigorously represented, while assessment and pedagogical experts verified that the diagnostic instruments accurately isolated student cognitive barriers without introducing structural ambiguities. These authoritative appraisals established that the instructional package met all stringent academic quality benchmarks before undergoing empirical classroom testing.

To ascertain the statistical significance of the academic improvements observed across the implementation trials, comprehensive non-parametric analyses were applied, given that preliminary normality tests confirmed non-normal data distributions within the sample groups (Meltzer, 2002). The application of the Wilcoxon Signed-Ranks Test yielded asymptotic significance values well below the established threshold of $p < 0.05$, thereby rejecting the null hypothesis and confirming that the score increases were statistically significant rather than mere statistical coincidences (Hake, 1999). Furthermore, the computation of normalized gain scores across the trial cohorts consistently positioned the intervention within the high effectiveness classification bracket, with N-gain metrics surpassing standard educational benchmarks. This robust quantitative validation underscores the reality that embedding ethnomathematical principles into structured instructional design exerts a powerful, measurable impact on cognitive mastery, spatial reasoning, and mathematical self-efficacy.

In addition to evaluating overall score gains, homogeneity testing was performed to verify the consistency of student capabilities across experimental cohorts, ensuring that the instructional intervention yielded uniform academic benefits regardless of group size configuration (Lim & Lim, 2022). Utilizing Levene's test for homogeneity of variance, the analysis yielded a significance value of $p = 0.294 > 0.05$, which statistically confirmed that participants across both small-group and large-group trials possessed equivalent baseline distributions and responded with comparable proficiency to the traditional game-based intervention. This statistical uniformity reinforces the internal validity of the study, demonstrating that the observed reduction in geometric misconceptions was a direct consequence of the instructional media rather than disparities in sample group composition or extraneous confounding variables.

Beyond aggregate score improvements and statistical homogeneity, the qualitative dimensions of the findings illuminate a critical reduction in specific geometric misconceptions and conceptual barriers that traditionally plague elementary students (Arikunto, 2021). Utilizing specialized diagnostic instruments, the study successfully isolated and tracked persistent student misunderstandings regarding the attributes, side properties, and classifications of two-dimensional plane shapes. Prior to the intervention, learners frequently conflated categorical definitions, misidentified parallel lines, or relied heavily on superficial visual prototypes without analytical justification. The integration of structured inquiry tasks embedded within the traditional game environment provided students with immediate tactile feedback, enabling them to reconstruct their internal cognitive schemas and resolve persistent conflicts regarding fundamental geometric properties.

The practical utility, operational feasibility, and systemic adoptability of the instructional media were further corroborated through comprehensive response evaluations administered to both educators and student participants (Van den Akker, 1999). Quantitative metrics derived from response questionnaires placed the product firmly within the highest feasibility and practicality classifications, indicating that the materials are intuitively structured, safe, durable, and readily implementable within standard classroom settings without imposing excessive administrative burdens on teachers. Qualitative observations corroborated these ratings, highlighting that the kinesthetics engagement inherent in traditional game formats effectively alleviated

classroom anxiety, fostered collaborative peer interaction, and sustained high levels of motivational drive throughout the learning process. These findings confirm that instructional tools must harmonize usability with pedagogical depth to achieve sustained classroom integration.

Synthesizing these multifaceted results leads to the overarching conclusion that bridging indigenous cultural practices with formal primary mathematics education offers a robust pedagogical solution to persistent learning challenges in contemporary schooling (Branch, 2009). The seamless alignment between Kurikulum Merdeka objectives, cognitive development theories, and contextual ethnomathematics creates an optimal ecosystem for meaningful mathematical sense-making and cultural preservation. By transforming abstract geometric concepts into tangible, culturally resonant physical experiences, the instructional media not only elevates quantitative outcomes but also cultivates deep-seated conceptual clarity and long-term retention among young learners. These insights provide a solid empirical foundation for future curriculum developments, advocate for the wider institutional integration of culturally responsive pedagogical tools, and establish a methodological standard for subsequent research in educational sciences.

Conclusion

This study concludes by comprehensively addressing its three core research problems concerning the development, feasibility, and effectiveness of traditional game-based ethnomathematics media for fourth-grade elementary students. First, the procedural development executed through the ADDIE instructional design framework successfully produced a structured, culturally integrated physical playmate media and guidebook designed to bridge formal mathematics with local cultural practices. Second, expert validation across media engineering, material content, assessment design, and pedagogical usability confirmed that the developed media achieved "very feasible" classifications with percentage scores ranging from 88.8% to 100%, indicating that the product meets high standards of academic quality. Third, empirical testing demonstrated that the media is highly effective in minimizing student geometric misconceptions and improving learning outcomes. Non-parametric analysis using the Wilcoxon Signed-Ranks Test yielded a statistically significant difference ($p < 0.001$) between pretest and posttest scores, while a high normalized N-gain score of 0.7286 confirmed substantial cognitive enhancement. Furthermore, educator and student response questionnaires established that the product is exceptionally practical for classroom deployment. Ultimately, integrating traditional ethnomathematical games into primary mathematics instruction provides a robust pedagogical solution that enhances conceptual retention, promotes active kinesthetic engagement, and supports the objectives of the Kurikulum Merdeka.

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