# Enhancing Geometric Proficiency in Fourth-Grade Students: A Tangram-Assisted, Ethnomathematics-Based Problem-Based Learning Approach

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**Abstract**
This study investigates the efficacy of a tangram-assisted, ethnomathematics-based Problem-Based Learning (PBL) model in enhancing the geometric proficiency of fourth-grade students. The research addresses fundamental pedagogical challenges: students' suboptimal comprehension of two-dimensional shapes, diminished learning engagement, and the prevalence of teacher-centered, lecture-dominant instruction lacking concrete manipulatives. Employing a Classroom Action Research (CAR) design rooted in the Kemmis and McTaggart framework, the study systematically executed two cyclical phases comprising planning, implementation, observation, and reflection. The participant cohort consisted of 13 fourth-grade students. Data were rigorously collected using structured observation sheets, geometric proficiency assessments, and instructional documentation. The findings indicate a substantial and progressive enhancement in students' geometric proficiency following the pedagogical intervention. Specifically, the mean class score exhibited a marked upward trajectory, advancing from a pre-cycle baseline of 60.19 to 74.81 in Cycle I, and culminating at 86.35 in Cycle II. Concurrently, classical mastery rates surged from an initial 23.08% to 69.23% in Cycle I, ultimately achieving a robust 92.31% in Cycle II. Furthermore, qualitative observations revealed a parallel increase in active student participation and classroom engagement throughout the learning process. In conclusion, the integration of a tangram-assisted, ethnomathematics-based PBL model serves as a highly effective instructional strategy for advancing geometric proficiency in elementary education.

## 1. Introduction

Contemporary mathematics education at the elementary level is increasingly oriented toward cultivating higher-order thinking skills (HOTS), encompassing analytical proficiency, logical reasoning, and spatial visualization. Within this paradigm, geometry emerges as a foundational domain; it is instrumental in equipping students to systematically comprehend relationships among shapes, positions, and dimensions, alongside spatial representations. Geometry instruction transcends the mere identification of two- and three-dimensional properties; it is fundamentally designed to instill visual interpretation capabilities and foster contextual problem-solving skills (Armelisa et al., 2025). Despite these pedagogical objectives, current instructional realities indicate that fourth-grade students continue to encounter substantial impediments to achieving optimal geometric comprehension. The persistence of mechanistic instructional paradigms characterized by a dearth of exploratory activities and the underutilization of concrete manipulatives often reduces geometric concepts to abstract notions. Consequently, this theoretical disconnect severely hampers the development of students' geometric proficiency.

Geometric proficiency is inextricably linked to students' cognitive development, particularly concerning spatial reasoning and visual representation. A robust mastery of geometric concepts empowers students to cultivate skills in pattern analysis, spatial structure comprehension, and the resolution of visually grounded mathematical problems (Susilowati et al., 2024). Furthermore, Amir et al. (2020) assert that integrating visual media and instructional technologies facilitates the construction of geometric understanding in a more concrete and structured manner. The incorporation of visual-based learning tools provides students with highly representative educational experiences, thereby enabling the translation of abstract concepts into comprehensible frameworks through direct observation. Consequently, the deployment of interactive instructional media emerges as a critical component in optimizing the efficacy of geometry instruction at the elementary school level.

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Beyond the deployment of instructional media, the efficacy of mathematics education is fundamentally contingent upon the adopted pedagogical model. A highly pertinent framework for cultivating mathematical thinking is Problem-Based Learning (PBL) (Mayoza et al., 2024). This model foregrounds instructional activities anchored in authentic problem-solving, thereby compelling students to independently conduct investigations, synthesize data, and execute informed decision-making. Throughout its implementation, learners assume an active role in formulating solutions, transforming the classroom into a participatory environment strictly oriented toward the advancement of critical thinking skills. Correspondingly, Resi Ratna Suminar et al. (2024) elucidate that integrating spatial reasoning within a PBL framework progressively enhances the geometric problem-solving proficiencies of elementary school students. This developmental trajectory is explicitly evidenced by students' augmented capacity to identify problem parameters, formulate strategic interventions, and critically evaluate their derived solutions.

The efficacy of Problem-Based Learning (PBL) is significantly optimized when synergized with an ethnomathematical approach. Fundamentally, ethnomathematics serves as a pedagogical framework that embeds local cultural elements into mathematics instruction. This paradigm aims to cultivate a contextualized learning environment by bridging abstract mathematical concepts with the socio-cultural realities inherent in the students' environment. Furthermore, Jampel and Antara (2025) postulate that ethnomathematics-based geometry instruction engenders learning experiences that are innovative, collaborative, and profoundly meaningful. By integrating local culture into the curriculum, students recognize that mathematical constructs are inextricably linked to societal practices, thereby rendering the educational process highly relevant to their lived experiences.

The ethnomathematical approach also significantly enhances students' motivation to learn. Integrating local cultural elements into instructional materials provides a learning experience that closely resonates with students' everyday realities, thereby substantially increasing their active engagement in the educational process. Furthermore, Diana and Kusuma (2025) demonstrate that Problem-Based Learning (PBL) modules integrated with ethnomathematics are highly effective in elevating the mathematical problem-solving proficiencies of elementary school students. Utilizing these local cultural contexts allows learners to decode abstract mathematical constructs through tangible and deeply meaningful experiential learning.

Within geometry instruction, the deployment of concrete manipulatives serves as a highly effective pedagogical strategy to assist students in conceptualizing abstract principles. A prominent example of such a tool is the tangram a manipulative consisting of dissected geometric polygons that can be reconfigured into diverse, specific formations. Tangrams afford learners the opportunity to directly explore spatial forms and the structural interrelationships among various geometric figures. Engaging with these tools facilitates the comprehension of foundational constructs, including area, symmetry, spatial patterns, and geometric composition, through constructive, hands-on activities. Furthermore, tangrams are instrumental in cultivating students' visual-spatial proficiencies and creative thinking via the systematic configuration of geometric shapes.

The efficacy of instructional media in elevating the quality of mathematics education is well-documented in contemporary literature. Specifically, Ardelina et al. (2021) demonstrate that integrating audiovisual instructional tools yields a significantly positive impact on student engagement and academic outcomes when compared to conventional pedagogical approaches. These findings underscore the strategic function of learning media in facilitating a more effective and compelling comprehension of complex subject matter. Consequently, the deployment of tangram manipulatives within geometry instruction is hypothesized to not only amplify student participation but also substantially fortify their geometric proficiency.

Another critical determinant of success in mathematics education is students' self-regulated learning. Tsaniyah et al. (2019) elucidate that innovative pedagogical models consistently yield superior academic outcomes among students exhibiting high levels of autonomous learning. Instructional activities anchored in exploration, peer discourse, and problem-solving effectively compel learners to construct knowledge independently. Within this paradigm, the implementation of a tangram-assisted Problem-Based Learning (PBL) model affords students the requisite environment to cultivate critical thinking, foster collaborative synergy, and resolve geometric challenges both autonomously and collectively.

A synthesis of extant literature indicates that contemporary geometry instruction necessitates pedagogical innovations integrating active learning models, contextualized approaches, and concrete manipulatives. Despite this pedagogical imperative, empirical studies specifically investigating the confluence of an ethnomathematics-based Problem-Based Learning (PBL) framework with tangram manipulatives among fourth-grade students remain notably scarce. This represents a critical gap in the literature, given that the integration of these three components holds profound potential to cultivate a geometry learning environment that is highly participatory, culturally resonant, and developmentally aligned with the cognitive characteristics of elementary learners.

Consequently, the present study aims to evaluate the enhancement of geometric proficiency among fourth-grade elementary students through the implementation of a tangram-assisted, ethnomathematics-based

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Problem-Based Learning (PBL) model. It is anticipated that these findings will contribute significantly to the advancement of instructional innovations in elementary mathematics education. Specifically, this research endeavors to foster a geometry learning environment that is highly effective, culturally contextualized, and deliberately oriented toward cultivating students' higher-order cognitive skills.

## 2. Method

This study employs a Classroom Action Research (CAR) design to enhance the geometric proficiency of fourth-grade elementary students through the implementation of a tangram-assisted, ethnomathematics-based Problem-Based Learning (PBL) model. The selection of this methodology is predicated on its fundamental orientation toward the direct remediation and enhancement of pedagogical practices within the authentic classroom environment. Consequently, the researcher transcends passive observation by systematically executing targeted pedagogical interventions designed to elevate the quality of mathematics instruction, with a specific focus on geometric concepts. The study adopts the iterative spiral model conceptualized by Kemmis and McTaggart, which encompasses four principal phases: planning, acting, observing, and reflecting. These phases are executed cyclically; the iterative process continues until the predetermined indicators of research success are optimally achieved.

This research was conducted during the even semester at a selected elementary school, utilizing fourth-grade students as the primary research cohort. The participant pool comprised 13 students (7 males and 6 females). The purposive selection of this cohort was predicated on findings from a preliminary investigation, which indicated critically low baseline levels of geometric proficiency. Specifically, this academic deficit manifested in the students' inability to identify the properties of two-dimensional figures, discern inter-shape relationships, and resolve geometric problems necessitating visual-spatial reasoning. Furthermore, student engagement during mathematics instruction was observed to be predominantly passive; prior pedagogical approaches relied heavily on traditional didactic lecture methods, thereby depriving students of opportunities for active, inquiry-based exploration and authentic problem-solving. Subsequently, Cycle II was designed to reinforce students' geometric problem-solving capacities. Informed by the critical reflections from the preceding cycle, this iteration introduced more complex tangram configurations, elevated the cognitive demand of the mathematical tasks, and optimized collaborative engagement. Throughout the entirety of the intervention, the pedagogical framework systematically compelled active student participation in investigation, peer dialogue, and spatial exploration, thereby cultivating a highly interactive and meaningful learning environment.

Data collection instruments comprised observation protocols, geometric proficiency assessments, and archival documentation. The observation protocols were utilized to systematically capture teacher and student engagement throughout the instructional process. Specifically, these protocols monitored the fidelity of the Problem-Based Learning (PBL) implementation, the deployment of tangram manipulatives, the extent of student participation in collaborative discourse, geometric problem-solving behaviors, and overall classroom interaction dynamics. To quantify academic achievement, a geometric proficiency test was administered at the conclusion of each iterative cycle to measure students' cognitive mastery of the material. This assessment instrument consisted of 10 multiple-choice items, three dichotomous (true-false) items, and two constructed-response (essay) items, yielding a maximum cumulative score of 100. Furthermore, supplementary documentation encompassing photographic evidence of instructional activities, student artifacts, grade registries, and empirical field notes was compiled to triangulate the primary data.

The analytical framework of this study employed a mixed-methods descriptive approach, integrating both quantitative and qualitative techniques. Quantitative data, derived from the geometric proficiency assessments, were evaluated by calculating the class mean scores and the percentage of individual academic mastery within each iterative cycle. An individual student was deemed to have achieved mastery upon obtaining a minimum threshold score of 70, strictly aligning with the institutional Minimum Mastery Criteria. Consequently, the overarching success of the intervention defined as classical mastery was established at a minimum of 75% of the total student cohort achieving a score of ≥ 70. Concurrently, qualitative data elicited from observation protocols and archival documentation were analyzed descriptively. This qualitative analysis was conducted to delineate shifts in instructional dynamics, levels of student engagement, and behavioral trajectories throughout the implementation of the pedagogical intervention.

The success of the research intervention was predicated on three primary criteria. Primarily, the class mean score for geometric proficiency must attain a minimum threshold of 75. Secondly, classical academic mastery must be achieved by at least 75% of the total student cohort. Thirdly, there must be a demonstrable enhancement in student engagement, empirically evidenced by heightened attentiveness, active participation, collaborative synergy, and the capacity to autonomously resolve geometric problems during the instructional process. Should all predetermined indicators be optimally satisfied within a given cycle, the iterative pedagogical intervention is formally concluded. Conversely, if these quantitative and qualitative benchmarks remain unmet, subsequent cycles are initiated. These subsequent iterations incorporate remedial pedagogical adjustments directly informed by a critical reflection on the instructional deficiencies identified in the preceding phase.

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# 3. Results and Discussion

## 3.1. Results

Prior to implementing the pedagogical intervention, preliminary observations and a diagnostic pretest were conducted to evaluate the baseline geometric proficiency of the fourth-grade students regarding two-dimensional shapes. Observational data indicated that mathematics instruction was predominantly characterized by teacher-centered didactic lectures and rote exercises, largely devoid of concrete manipulatives or active problem-solving tasks. This overreliance on direct instruction rendered the students largely passive during the learning process. Consequently, students exhibited a superficial understanding of geometric concepts, relying heavily on the mere memorization of shapes and formulas.

Furthermore, a substantial majority of the students encountered notable difficulties in identifying the fundamental properties of two-dimensional shapes, determining spatial relationships between distinct figures, and resolving geometry-based word problems. The students' lack of familiarity with tactile manipulative media in mathematics instruction severely hindered the optimal development of their visuospatial skills. This diminished student engagement fostered a monotonous classroom environment characterized by low interactivity and minimal cognitive stimulation.

The pretest results empirically corroborated these observations, revealing that only three out of the 13 students (23.08%) achieved the Minimum Mastery Criteria, leaving the remaining 10 students (76.92%) below the required mastery threshold. The baseline class mean score stood at 60.19, with individual scores ranging from a minimum of 42.5 to a maximum of 80. These suboptimal academic outcomes underscore the critical necessity to systematically enhance students' geometric proficiency through the integration of an innovative pedagogical model that prioritizes direct, hands-on learning activities.

In light of these baseline findings, an instructional intervention is imperative to facilitate a concrete, contextualized, and highly engaging comprehension of geometric concepts. To address this pedagogical exigency, the current study implements an ethnomathematics-based Problem-Based Learning (PBL) model, augmented by tangram manipulatives, with the explicit aim of elevating the geometric proficiency of fourth-grade students.

The instructional intervention in Cycle I operationalized the tangram-assisted, ethnomathematics-based Problem-Based Learning (PBL) model, focusing specifically on two-dimensional geometric properties. Initially, the instructor introduced the tangram manipulatives, demonstrating their application in composing diverse geometric configurations. The pedagogy was anchored in contextualized problem-solving tasks integrated with local cultural artifacts, thereby facilitating a more concrete and meaningful comprehension of abstract geometric concepts.

Observational data indicated a marked increase in student engagement during these sessions compared to the baseline pre-cycle conditions. The integration of tangram manipulatives catalyzed student interest, as the tactile affordances allowed them to physically manipulate spatial forms. Furthermore, the collaborative discourse inherent to the PBL framework compelled students to synthesize ideas, negotiate peer perspectives, and autonomously navigate geometric problem-solving scenarios.

Subsequent quantitative assessments via the Cycle I posttest revealed a substantive improvement in geometric proficiency following the intervention. Specifically, nine students (69.23%) successfully surpassed the Minimum Mastery Criteria, while four students (30.77%) remained below the requisite mastery threshold. Concurrently, the class mean score advanced to 74.81, with individual performances ranging from a minimum of 55 to a maximum of 95.

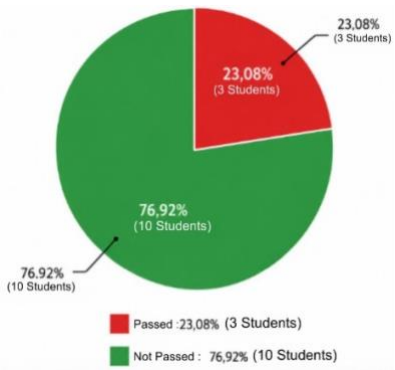



**Figure 1. Pre-Cycle Results Completeness Pie Chart**

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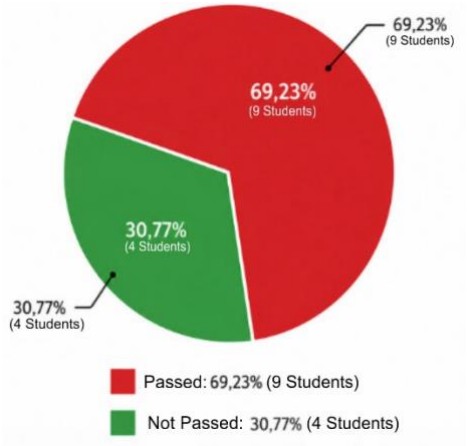



**Figure 2. Circle I Learning Mastery Pie Chart**

The execution of Cycle II was predicated on the critical reflections derived from Cycle I. To address the previously identified pedagogical constraints, several targeted instructional refinements were instituted. These included the provision of incremental scaffolding for tangram application, intensified instructional support for students exhibiting conceptual difficulties, and the explicit delineation of collaborative roles within peer groups. Furthermore, the instructional design incorporated a more diverse array of ethnomathematical geometry problems, purposefully aligned with the students' local cultural context and lived experiences to maximize cognitive engagement.

During this second cycle, the instructional environment became markedly more conducive and interactive. Student enthusiasm was notably heightened a shift largely attributable to their newly acquired fluency with tangram manipulatives in spatial configuration tasks. Collaborative discourse functioned more dynamically; students demonstrated an enhanced capacity to articulate their mathematical reasoning and present their problem-solving outcomes with substantially greater self-efficacy than in the preceding iteration.

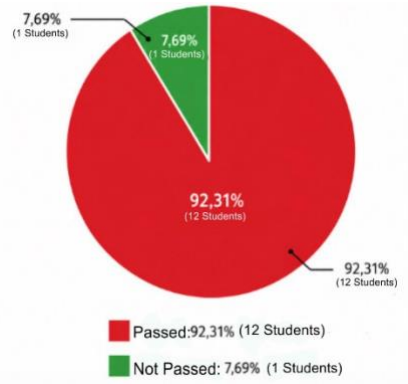



**Figure 3. Cycle II Learning Mastery Pie Chart**

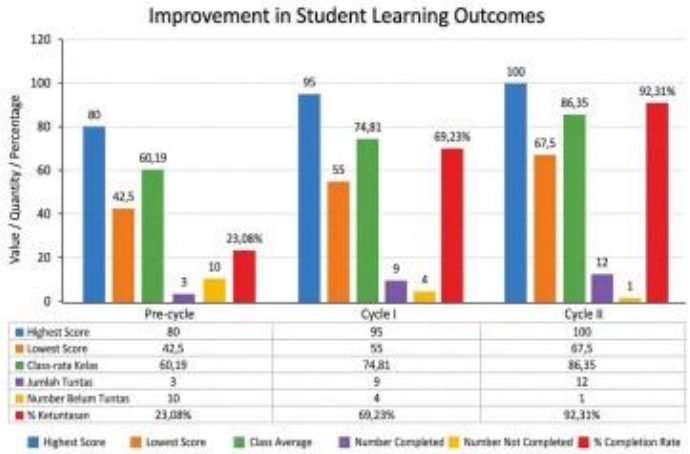



**Figure 4. Student Learning Outcomes Improvement Bar Chart Results of Cycle II**

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Quantitative assessments via the Cycle II posttest revealed a substantial enhancement in students' geometric proficiency. The proportion of students surpassing the Minimum Mastery Criteria surged to 12 individuals (92.31%), leaving only a single student (7.69%) below the requisite mastery threshold. Concurrently, the class mean score advanced significantly to 86.35, with individual academic performances ranging from a minimum of 67.5 to a maximum perfect score of 100.

The enhancement of academic outcomes observed in Cycle II demonstrates that the implementation of the tangram-assisted, ethnomathematics-based Problem-Based Learning (PBL) model progressively and significantly elevates students' geometric proficiency. Students developed a more intuitive and robust comprehension of two-dimensional geometric concepts, primarily because the pedagogical framework prioritized concrete tactile activities, active spatial exploration, and experiential problem-solving over passive instruction.

## 3.2. Discussion

Effective geometry instruction at the elementary level necessitates pedagogical strategies that actively engage students in higher-order thinking and problem-solving processes. Empirical findings from this study demonstrate that the implementation of a tangram-assisted, ethnomathematics-based Problem-Based Learning (PBL) model progressively enhances the geometric proficiency of fourth-grade students across successive instructional cycles. This enhancement is quantitatively evidenced by the sequential increase in both the class mean score and the proportion of students surpassing the Minimum Mastery Criteria from the pre-cycle baseline through Cycle II. Ultimately, these outcomes substantiate that instructional environments affording direct, tactile exploration of geometric forms significantly facilitate the robust assimilation of abstract mathematical concepts.

The observed enhancement in students' geometric proficiency is largely attributable to the Problem-Based Learning (PBL) model, which situates learners at the center of the instructional process through active problem-solving engagements. Rather than passively receiving didactic instruction, students are systematically trained to deconstruct problems, engage in collaborative discourse, formulate solutions, and articulate their cognitive processes. Consequently, this pedagogical environment significantly amplifies student engagement and active participation. These findings corroborate the assertions of Krisanti and Kusuma (2024), who posited that ethnomathematics-infused PBL effectively elevates the mathematical problem-solving capabilities of elementary students by directly immersing them in critical thinking and contextualized problem-solving activities.

The integration of an ethnomathematical approach in this study provided a highly contextualized learning experience that resonated with the students' lived realities. By linking geometric instruction to local cultural elements, students were able to recognize the ubiquitous presence of mathematical concepts within their immediate environment. This cultural contextualization facilitated a more intuitive grasp of two-dimensional shapes and their properties, as abstract theoretical material was mediated through familiar paradigms. These outcomes are strongly supported by Hariyadi and Muttaqin (2020), who demonstrated that ethnomathematics-integrated PBL enhances students' conceptual understanding of geometry by rendering the learning process inherently more meaningful and accessible to elementary learners.

The enhancement in students' geometric proficiency was also driven by the utilization of tangram manipulatives as an instructional scaffold. Tangrams facilitate a concrete understanding of two-dimensional shapes through direct, tactile activities involving the arrangement, combination, and physical manipulation of geometric pieces. The deployment of such concrete media enables a more intuitive grasp of spatial concepts compared to relying solely on verbal instruction or static textbook illustrations. During the intervention, students exhibited heightened enthusiasm and engagement while utilizing tangrams, as the manipulatives afforded opportunities for exploratory, play-based learning. These findings corroborate Khairi et al. (2026), who demonstrated that integrating tangram manipulatives within a Problem-Based Learning (PBL) framework significantly enhances both critical thinking skills and student engagement in elementary mathematics education.

Instructional success was substantially influenced by the integration of problem-solving activities grounded in local cultural contexts. In this study, students were presented with geometric problems explicitly linked to cultural artifacts and objects within their immediate environment, thereby rendering the pedagogical process highly realistic. This contextual approach successfully bridged the conceptual gap between abstract mathematics and the students' daily lives. This aligns with Fitriyah et al. (2024), who established that ethnomathematics-based PBL models effectively stimulate active learning by situating academic content within the students' authentic, lived experiences.

Additionally, the findings indicate that culturally contextualized geometry instruction significantly bolsters students' visual-spatial competencies. By examining two-dimensional figures through the dual lenses

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of local cultural elements and tangram manipulatives, students demonstrated an accelerated capacity to identify geometric patterns, structural forms, and inter-shape relationships. This cognitive environment catalyzed the development of visual thinking, a foundational skill in elementary mathematics. This phenomenon is supported by Kurino and Rahman (2022), who articulated that ethnomathematical explorations of traditional architecture (rumah adat) provide rich, concrete pedagogical resources for geometry, as they embed both two- and three-dimensional concepts that facilitate profound conceptual assimilation.

the implementation of the tangram-assisted, ethnomathematics-based Problem-Based Learning (PBL) model cultivated a highly dynamic, engaging, and interactive instructional environment. Students exhibited heightened self-efficacy when articulating their perspectives, participating in collaborative peer discourse, and presenting their problem-solving outcomes to the class. These pedagogical activities successfully facilitated the development of both mathematical communication and collaborative skills. This aligns with the findings of Widyaningrum and Rani (2025), who posited that ethnomathematics-based PBL effectively enhances students' mathematical problem-solving capacities by systematically training them in active, collaborative cognitive processes.

Cumulatively, the findings of this study demonstrate that the application of the tangram-assisted, ethnomathematics-based PBL model substantially improves the geometric proficiency of fourth-grade students. This instructional success is primarily driven by the synergy of active problem-solving engagements, the deployment of concrete manipulatives, and the integration of local cultural elements, all of which render the learning experience highly contextualized and cognitively meaningful. These conclusions are further corroborated by Safitri et al. (2020), who demonstrated that ethnomathematics-infused PBL in geometry instruction elevates elementary students' academic outcomes by fostering active spatial exploration through direct, experiential learning.

## 3.3. Implications

The empirical findings of this study offer significant theoretical, practical, and policy implications that extend beyond the immediate context of elementary geometry education. Theoretically, this research enriches the existing body of mathematics education literature by providing robust evidence that the synergistic integration of an ethnomathematics-based Problem-Based Learning (PBL) framework with tangram manipulatives effectively bridges the cognitive gap between abstract geometric concepts and students' concrete realities. By contextualizing spatial problem-solving within local cultural paradigms, this study affirms that the physical manipulation of tactile media accelerates the development of visual-spatial reasoning and higher-order thinking skills among elementary learners.

On a practical level, these findings present a transformative pedagogical blueprint for educators seeking to transition away from mechanistic, teacher-centered instruction. The substantial increase in classical mastery surging from a baseline of 23.08% to an impressive 92.31% demonstrates the profound efficacy of this instructional intervention in resolving issues of passive student engagement and suboptimal academic performance. Consequently, elementary school teachers are strongly encouraged to adopt this collaborative, inquiry-driven model. By utilizing tangible artifacts like tangrams to explore culturally relevant geometric problems, educators can significantly optimize classroom interactivity, foster active peer discourse, and enhance students' mathematical communication and self-efficacy.

From a broader educational and policy perspective, this research provides evidence-based insights for curriculum developers and institutional administrators. The findings highlight the critical necessity of explicitly integrating ethnomathematical elements into mathematics curricula to ensure that learning remains culturally resonant and cognitively meaningful. Furthermore, educational policymakers must prioritize the allocation of resources to equip classrooms with adequate manipulative learning tools, given their proven role in solidifying foundational geometric comprehension. Finally, the success of this instructional design underscores the imperative for targeted professional development programs that equip teachers with the pedagogical competencies required to implement complex PBL frameworks, thereby advancing spatial literacy and analytical problem-solving across wider educational contexts.

## 3.4. Limitations

Despite the significant improvements observed in students' geometric proficiency, this study acknowledges several methodological and contextual limitations that should be considered when interpreting the findings. First, the research was conducted with a highly localized and relatively small sample size, consisting of only 13 fourth-grade students within a single elementary school. Consequently, while the intervention proved highly effective within this specific cohort, the statistical generalizability of the findings to broader, more demographically diverse educational populations remains constrained. Second, the adoption of a Classroom Action Research (CAR) design inherently prioritizes the remediation of localized pedagogical issues and the improvement of specific classroom practices over the establishment of universal empirical generalizations. The

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observed outcomes are, therefore, deeply intertwined with the unique instructional dynamics and the specific socio-academic environment of the participating class.

Furthermore, the ethnomathematical approach utilized in this study was deliberately tailored to resonate with the specific local cultural context of the students. While this contextualization was a primary catalyst for engagement, it also implies that the specific instructional modules and geometric problems cannot be universally applied; they would necessitate careful cultural adaptation before implementation in different geographical or cultural regions. Finally, the study evaluated academic progress over a relatively brief period spanning two instructional cycles, leaving the longitudinal retention of these newly acquired visual-spatial skills unexplored. To build upon these findings, future research should consider employing quasi-experimental or longitudinal designs with larger, multi-site cohorts to validate the broader applicability, scalability, and long-term efficacy of the tangram-assisted, ethnomathematics-based Problem-Based Learning model.

## 4. Conclusion

Based on the empirical findings of this study, it can be concluded that the implementation of a tangram-assisted, ethnomathematics-based Problem-Based Learning (PBL) model substantially enhances the geometric proficiency of fourth-grade elementary students. This enhancement is evidenced by a consistent upward trajectory in both the class mean score and the classical mastery rate across consecutive instructional cycles. The PBL framework compelled students to actively engage in geometric problem-solving through collaborative discourse, spatial exploration, and peer cooperation. Furthermore, the integration of the ethnomathematical approach scaffolded students' comprehension by anchoring abstract geometric concepts within familiar, daily cultural contexts. Concurrently, the tangram manipulatives provided a concrete, tactile learning experience that directly augmented their visual-spatial cognitive skills. Beyond measurable academic achievement, this pedagogical intervention elevated student participation, intrinsic motivation, and academic self-efficacy throughout the mathematics instruction. Therefore, the tangram-assisted, ethnomathematics-based PBL model serves as a highly viable and innovative pedagogical alternative for elementary geometry instruction.

## Author Contributions

All authors contributed equally to this paper. All authors have read and approved the final manuscript.

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## Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

## Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

## Declaration on AI Use

The authors declare that no artificial intelligence (AI) or AI-assisted tools were used in the preparation of this manuscript.

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