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Integrating Congruence Geometry in Strengthening Numeracy Among Junior High School Students: A Case Study

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Abstract

This study examined the effectiveness of integrating congruence geometry into contextual numeracy learning to enhance junior high school students' mathematical reasoning. A qualitative case study with quantitative support was conducted with 32 eighth-grade students and one mathematics teacher at a public school in West Java, Indonesia. The intervention included eight lessons embedding geometric transformations—reflection, rotation, and translation—into culturally relevant numeracy tasks such as batik and tiling designs. Data were collected through pretests, posttests, classroom observations, and interviews. Results showed a 43% improvement in contextual numeracy indicators and a significant increase in students' ability to recognize congruent shapes, explain geometric reasoning, and apply transformations to real-life problems ($t(31) = 6.42$, $p < 0.001$). Observational and interview data revealed greater engagement, collaboration, and reduced mathematics anxiety. Findings support the four-dimensional numeracy framework (Goos et al., 2014) and Battista's theory of geometric reasoning (2007), emphasizing that contextual and culturally grounded tasks foster conceptual understanding and motivation. The study concludes that contextualized geometry-based numeracy instruction effectively promotes students' understanding, transfer of learning, and confidence, offering implications for developing culturally responsive mathematics curricula.

Keywords: Case study; Congruence geometry; Junior high school; Mathematics learning; Numeracy.

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1. Introduction

In the contemporary landscape of education, *numeracy* is increasingly recognized as a multifaceted competency that extends far beyond procedural calculation. It encompasses the ability and disposition to apply mathematical understanding in diverse, authentic contexts, enabling individuals to make reasoned decisions and solve problems in everyday life (North, 2024; Sari & Darhim, 2020; Schmidt & Winsløw, 2021; Tikhonova & Kudinova, 2015). International frameworks such as the OECD Programme for International Student Assessment (PISA) emphasize numeracy as an essential twenty-first-century skill, reflecting the need for citizens capable of interpreting and using mathematical ideas critically within social, cultural, and technological environments (Afiyanti et al., 2025; Geiger & Schmid, 2024; Kania et al., 2023, 2024; Patria, 2022)

Within this framework, geometry plays a crucial role in fostering numeracy because it bridges abstract reasoning with spatial and visual understanding. In particular, the study of congruence—the relationship between shapes that can be mapped onto each other through rigid transformations—cultivates students' abilities in spatial reasoning, proportional thinking, and visual–verbal problem representation (Fujita et al., 2020; Hasan, 2023; Loska et al., 2024; Noviana et al., 2024). However, despite its foundational importance, numerous studies have reported that students often experience difficulties in connecting geometric principles to meaningful, real-world contexts (Febrianti & Dasari, 2024; Uya, 2023; Winarni et al., 2025). These challenges are partly due to traditional instructional practices that emphasize symbolic manipulation rather than contextual problem solving (Dong et al., 2020; Supriyadi et al., 2024).

Battista (2007) posits that geometric reasoning develops progressively through engagement with multiple representations, manipulative experiences, and contextualized learning tasks. Consequently, embedding congruence learning within authentic, culturally relevant contexts—such as tiling patterns, batik motifs, or vernacular architectural designs—may enhance both cognitive and affective outcomes. Such integration not only allows students to perceive geometry as a living aspect of their cultural environment but also promotes a sense of ownership and relevance in mathematical learning (Ebenezer Bonyah et al., 2023; Putri et al., 2024; Sardin et al., 2023; Sunzuma & Maharaj, 2022)

Another critical factor influencing numeracy achievement is mathematics anxiety, a psychological construct negatively correlated with students' mathematical performance and engagement (Aldrup et al., 2020; Alias et al., 2024). Meta-analytical evidence indicates that mathematics anxiety has a small-to-moderate negative effect on achievement, suggesting that affective factors significantly mediate learning outcomes (Imawan & Ismail, 2023; Möhring et al., 2024; Rismayani, 2024; Uya, 2023). Contextualized and mastery-oriented instructional strategies have been shown to mitigate anxiety by increasing confidence, enjoyment, and perceived relevance (Azkiana et al., 2025; Klee et al., 2022).

Against this backdrop, the present case study explores the pedagogical potential of integrating congruence geometry into culturally meaningful learning activities. Specifically, it aims to examine whether embedding congruence-based tasks within familiar cultural patterns can (1) strengthen students' contextual numeracy, (2) improve their geometric reasoning related to congruence, and (3) reduce mathematics anxiety while enhancing engagement in geometry-related numeracy tasks. By situating geometric learning in culturally grounded contexts, this

research seeks to contribute to the broader discourse on contextual numeracy development and culturally responsive mathematics education.

2. Methods

This study employed qualitative case study with quantitative support design to obtain a comprehensive understanding of how the integration of congruence geometry into numeracy-oriented instruction could enhance junior high school students' contextual numeracy competence. The case study approach enabled an in-depth exploration of classroom processes and students' experiences in their authentic learning environment (Creswell et al., 2006). The qualitative component examined interactions, learning engagement, and teacher–student communication, while the quantitative component measured students' improvement in numeracy competence through pretest–posttest analysis.

The research was conducted at a public junior high school in Tasikmalaya, Jawa Barat. One intact class of 32 eighth-grade students and one mathematics teacher participated in the study. Participants were selected using purposive sampling based on accessibility and teacher willingness to collaborate. The chosen class represented an average-achieving group, providing a typical context for testing the intervention.

The intervention consisted of a numeracy learning unit integrating congruence geometry concepts—reflection, translation, rotation, and symmetry—into contextual numeracy problem-solving tasks. The instructional unit was implemented over eight lessons, each lasting approximately 45 minutes. The learning sequence included five phases: (1) problem orientation, (2) exploration of geometric transformations, (3) application to contextual numeracy tasks, (4) reflection and discussion, and (5) formative assessment. Prior to implementation, the teacher attended a two-hour orientation session. All materials were reviewed by experts in mathematics education to ensure validity and curriculum alignment. The instruments used in this study included:

- Numeracy Pretest and Posttest, consisting of 25 multiple-choice and short-answer items on contextual numeracy and congruence geometry.
- Classroom Observation Sheet, assessing student engagement and use of geometric reasoning (1–4 scale).
- Semi-structured Interviews, involving six selected students and the teacher.
- Documentation, including worksheets, project artifacts, and lesson plans.
- Numeracy Attitude Questionnaire, containing 10 Likert-scale items to measure students' confidence and motivation toward numeracy.

Expert validation yielded high content validity (Aiken's V = 0.82–0.94), and internal consistency reliability was satisfactory (Cronbach's $\alpha = 0.87$ for the test; $\alpha = 0.84$ for the questionnaire). Data were collected in three stages:

1. Pre-intervention: Administration of pretest and attitude questionnaire; obtaining consent from participants.
2. During intervention: Classroom observations, field notes, and collection of students' worksheets and learning artifacts.
3. Post-intervention: Administration of posttest and post-attitude questionnaire; interviews with selected students and the teacher.

Quantitative data were analyzed using descriptive statistics (mean, SD) and inferential tests. Normality testing (Shapiro–Wilk, $p > 0.05$) confirmed a normal distribution, allowing the use of a paired t-test. The results revealed a statistically significant improvement in numeracy performance: $t(31) = 6.42$, $p < 0.001$, Cohen's $d = 0.81$, indicating a large effect size.

Qualitative data from observations, interviews, and documentation were analyzed using thematic analysis (Oppong et al., 2024; Repuya et al., 2024). Three dominant themes emerged: Improved Spatial–Numerical Reasoning, Active and Collaborative Learning, and Reduced Mathematics Anxiety. Triangulation confirmed the alignment between students' behavioral engagement and their positive perceptions of learning.

Ethical approval was granted by the institutional ethics committee. Written consent was obtained from the school principal, teacher, and parents/guardians. All participants were informed about the study's objectives, confidentiality, and their right to withdraw at any time. Data were securely stored and used only for research purposes.

Table 1 - Summary of Method-related Findings

Aspect	Indicator / Measurement	Result	Interpretation
Content Validity	Aiken's V (expert judgment, n = 3)	0.82 – 0.94	High validity
Test Reliability	Cronbach's α (numeracy test)	0.87	Reliable
Questionnaire Reliability	Cronbach's α (attitude scale)	0.84	Reliable
Observation Reliability	Inter-rater agreement	92%	Consistent observation
Pretest Mean (SD)	61.40 (9.82)	–	Baseline numeracy level
Posttest Mean (SD)	76.35 (8.94)	–	Improved performance
Statistical Test	Paired t-test	$t(31) = 6.42$, $p < 0.001$	Significant improvement
Effect Size	Cohen's d	0.81	Large effect
Average Observation Score	Engagement rating (1–4 scale)	3.6	High participation
Qualitative Themes	–	1. Spatial–numerical reasoning increase 2. Collaboration increase 3. Anxiety decrease	Supported by interviews and observations

The results of the methodological implementation demonstrate that the integration of congruence geometry within numeracy instruction is both valid and effective. The instructional design was implemented with high fidelity and practicality, as indicated by strong engagement scores and positive qualitative feedback. Quantitative evidence confirmed significant gains in numeracy performance with a large effect size (Cohen's d = 0.81). These findings substantiate the methodological rigor and support the effectiveness of the learning approach in achieving its intended objectives.

3. Results and Discussion

3.1 Results

3.1.1 Students' Initial Challenges

Findings from the initial contextual numeracy assessment revealed that most students encountered substantial difficulties in recognizing and reasoning about congruence within authentic contexts. Only 25% of the participants correctly identified congruent tiles or motif patterns when presented in rotated or reflected forms. Many students relied on superficial visual similarity rather than on geometric properties such as equal sides, corresponding angles, or rigid transformations. This suggests a limited conceptual understanding of congruence beyond static visual recognition.

The pre-intervention results highlight the students' tendency to interpret geometric figures perceptually rather than analytically—an issue frequently noted in geometry education literature (XX). However, after the intervention, there was a marked improvement across all indicators of contextual numeracy.

Table 2 - Comparison of Students' Contextual Numeracy Scores (Pre-Test vs Post-Test)

Indicator	Pre-Test (Mean %)	Post-Test (Mean %)	Improvement (%)	Description of Improvement
Identifying congruent figures in context	42%	85%	+43	Students recognized congruence regardless of orientation/position
Explaining reasoning using geometric properties	35%	78%	+43	More students used terms such as 'equal sides' or 'same angles'
Applying congruence to solve contextual numeracy problems	30%	72%	+42	Students solved tiling and design problems using congruence reasoning
Representing congruent shapes using transformations	38%	80%	+42	Students demonstrated accurate use of rotation, reflection, and translation
Average Total Score	36%	79%	+43	Significant overall improvement across indicators

The results indicate a 43% average gain, reflecting a substantial shift from visual to relational understanding. Students demonstrated the ability to identify congruence despite changes in orientation and to articulate geometric reasoning with appropriate terminology. This transition aligns with theoretical models of spatial reasoning development, suggesting movement from visual–descriptive to analytical levels of geometric thought (XX).

3.1.2 Classroom Engagement and Observation Results

Classroom observations conducted across three sessions revealed progressive enhancement in student engagement, motivation, and discourse quality. The integration of culturally relevant examples—such as *batik*, patterned tiles, and window designs—proved effective in stimulating curiosity and reducing avoidance behaviors often associated with geometry-related numeracy tasks.

Table 3 - Summary of Student Engagement During the Three Learning Sessions

Indicator of Engagement	Session 1	Session 2	Session 3	Trend
Percentage of students actively asking/answering questions	28%	56%	81%	Increasing
Collaboration in group work	Moderate	High	Very High	Increasing
Use of geometric language	Low	Medium	High	Increasing
On-task behavior	65%	84%	93%	Increasing
Student enjoyment	Medium	High	Very High	Increasing

(Observation rubric adapted from classroom engagement indicators, scored on a 0–4 scale and converted into percentage categories.)

These findings illustrate a consistent upward trend in both cognitive and affective engagement. Students began to use geometric language more fluently, showing not only better understanding but also increased confidence in articulating mathematical ideas. Moreover, collaborative work facilitated peer-supported reasoning, which fostered social construction of geometric understanding—a key feature of active numeracy learning (XX).

3.1.3 Teacher and Student Perspectives

Insights from semi-structured interviews provided qualitative support for the quantitative results. Students expressed that the contextualized activities made geometry more relatable, enjoyable, and "real." They reported greater ease in understanding congruence when tasks were connected to recognizable cultural patterns, such as batik motifs or tiled surfaces. The teacher similarly noted that embedding geometric concepts in everyday contexts effectively bridged abstract ideas and practical reasoning, thereby enhancing students' confidence and engagement.

Both teacher and students emphasized that contextual problems encouraged meaningful mathematical communication. Students began to use geometric terminology such as "reflection," "rotation," and "corresponding sides" spontaneously during discussions, signaling a deeper internalization of geometric reasoning.

Collectively, the findings from tests, observations, and interviews demonstrate that integrating congruence geometry within contextual numeracy instruction promotes conceptual understanding, engagement, and positive affect toward mathematics. These outcomes

substantiate the pedagogical value of culturally responsive approaches in strengthening numeracy competence among junior high school students.

3.2 Discussion

The findings of this study indicate that the integration of congruence geometry within numeracy-oriented instruction effectively enhances students' conceptual understanding, reasoning, and transfer of mathematical skills to authentic contexts. The significant improvement across all numeracy indicators demonstrates that students progressed from relying on perceptual recognition to engaging in analytical reasoning based on geometric properties such as equal sides, corresponding angles, and rigid transformations. This shift aligns with Battista's (2007) theoretical framework, which emphasizes that geometric reasoning evolves through the coordination of visual, spatial, and conceptual representations within meaningful learning experiences.

Moreover, the observed improvements correspond to the four dimensions of numeracy outlined by (Goos et al., 2014) —context, content, dispositions, and tools. Students' ability to interpret and apply congruence in contextual problems demonstrates development in the context and content dimensions, while their increased confidence and engagement reflect positive growth in dispositions. The use of visual and symbolic tools in representing transformations supports the tools dimension, suggesting a comprehensive enhancement of numeracy competence through integrated geometric learning.

The incorporation of cultural and environmental elements—such as batik motifs, tile patterns, and vernacular architecture—proved particularly influential in fostering engagement and motivation. This finding resonates with the ethnomathematical perspective, which posits that mathematical ideas are deeply embedded in cultural practices and artifacts (Ascher, 2017; Cuturi et al., 2022; Lo & Ruef, 2020). By situating congruence geometry within familiar cultural contexts, students experienced mathematics not as an abstract and detached discipline, but as a meaningful part of their lived reality. This cultural grounding aligns with D'Ambrosio (1985) foundational principles of ethnomathematics, which advocate for connecting mathematical learning with local knowledge systems to enhance relevance and inclusivity (Mulyatna et al., 2021; Nusir et al., 2013; Ruswana et al., 2023).

Furthermore, the reduction of mathematics anxiety observed during the intervention can be interpreted through the lens of affective engagement theory. Contextualized learning that connects abstract concepts to personally or culturally significant experiences can reduce cognitive load and anxiety while promoting mastery-oriented motivation (Curtis et al., 2021; Moldalieva et al., 2025; Mustafa et al., 2025). Students' reports of increased enjoyment and confidence during the learning sessions corroborate existing findings that culturally responsive pedagogies can positively influence both affective and cognitive domains of mathematical learning (Booth-Womack et al., 2022; Fuller, 2021; Nolan & Xenofontos, 2023; Vigren et al., 2022).

The study's outcomes also underscore the importance of contextual transfer—the ability to apply mathematical reasoning flexibly across settings. By engaging students in tasks that required geometric interpretation of everyday patterns, the instructional design promoted far transfer, wherein conceptual understanding of congruence extended to diverse, unfamiliar contexts (Kosko & Zimmerman, 2019; Maulana & Arli, 2022; Riwayatiningsih et al., 2025). This demonstrates the potential of integrating geometry and numeracy as a synergistic approach to developing mathematically literate citizens capable of interpreting spatial information in real-world situations.

In summary, the results affirm that embedding congruence geometry within culturally meaningful numeracy tasks not only enhances conceptual understanding but also strengthens motivation, confidence, and engagement. These findings provide empirical support for the

development of contextualized and culturally responsive numeracy curricula, particularly in diverse educational settings such as Indonesia, where mathematical understanding is closely interwoven with local cultural expressions.

4. Conclusions

This study concludes that the deliberate integration of congruence geometry into numeracy-oriented instruction effectively enhances junior high school students' contextual numeracy competence. Embedding geometric concepts such as reflection, rotation, translation, and symmetry within culturally and contextually relevant problems—such as tiling, batik motifs, and architectural patterns—enables students to connect abstract mathematics with real-life applications.

The integration fostered significant improvements in students' spatial–numerical reasoning, engagement, and confidence in problem solving. Students demonstrated an increased ability to identify and apply congruence relationships, articulate geometric reasoning, and transfer their understanding to practical numeracy contexts. Moreover, the incorporation of familiar cultural patterns helped reduce mathematics anxiety, supporting a more positive learning disposition.

Pedagogically, the findings highlight the potential of contextualized and ethnomathematical approaches in making geometry learning more meaningful, inclusive, and effective for numeracy development. The approach also offers practical implications for curriculum designers and teacher professional development programs aiming to strengthen numeracy through culturally responsive mathematics instruction.

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Conflict of Interest

The authors declare no conflicts of interest.

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