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Developing Mathematical Literacy Through Geometry Instructional Media: A Quasi-Experimental Study in Middle School Education

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ABSTRACT:
Background: Mathematical literacy is a fundamental component of contemporary education because it enables students to interpret, represent, and apply mathematical ideas in meaningful contexts. However, many middle school students experience difficulties in developing mathematical representation skills, particularly in geometry learning, due to the abstract nature of concepts and limited use of effective instructional media. These challenges hinder students' ability to connect mathematical ideas with real-world situations, which is a core objective of literacy-oriented education.
Aims: This study aims to examine the effectiveness of geometry instructional media in developing students' mathematical literacy, with a specific focus on improving their mathematical representation skills in middle school learning contexts.
Method: The study employed a quasi-experimental design with a pretest–posttest control group. A total of 60 eighth-grade students were selected through purposive sampling and divided into experimental and control groups. The experimental group received geometry instruction supported by instructional media, while the control group was taught using conventional methods. Data were collected using a validated mathematical representation ability test and analyzed through descriptive statistics, independent sample t-tests, and effect size calculations.
Result: The findings revealed a statistically significant difference between the two groups. Students in the experimental group demonstrated higher posttest scores in mathematical representation skills compared to those in the control group, indicating that geometry instructional media effectively enhanced students' mathematical literacy.
Conclusion: The study concludes that integrating geometry instructional media into classroom instruction plays a critical role in fostering mathematical literacy by strengthening students' ability to represent mathematical ideas visually, symbolically, and contextually. Instructional media support deeper conceptual understanding, promote active engagement, and bridge abstract mathematical concepts with real-life applications. These findings highlight the pedagogical importance of literacy-oriented instructional strategies in mathematics education and suggest that the systematic use of instructional media can contribute to more meaningful, inclusive, and effective learning experiences in middle school settings.
Keywords: geometry instruction, instructional media, mathematical literacy, mathematical representation, middle school education

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INTRODUCTION

Mathematical literacy has become a central concern in contemporary education as it equips students with the ability to interpret, represent, and apply mathematical ideas in diverse contexts. International educational frameworks emphasize that literacy in mathematics is not limited to procedural skills but includes representation, reasoning, and communication abilities that support lifelong learning (Geiger et al., 2023). Despite its importance, many middle school students demonstrate limited mathematical literacy, particularly when engaging with geometry concepts that are highly abstract in nature (Adams et al., 2023). Geometry learning often relies on symbolic explanations that are disconnected from students' everyday experiences, resulting in shallow conceptual understanding (Agustito et al., 2025). This condition becomes more critical when students are required to express mathematical ideas through visual, symbolic, or verbal representations. Research indicates that weak representation skills hinder students' capacity to construct meaning and solve problems effectively (Worku et al., 2025). Consequently, addressing mathematical literacy through instructional innovation is an urgent educational priority. These challenges position geometry learning as a strategic entry point for strengthening literacy-oriented mathematics education.

The urgency of this study is further reinforced by the increasing demand for instructional approaches that integrate literacy skills into mathematics classrooms. Recent studies suggest that effective mathematics instruction should foster students' ability to read, interpret, and communicate mathematical information across multiple representations (Post & Prediger, 2024). However, classroom practices in many educational settings still prioritize memorization and routine problem solving over meaningful representation. This instructional gap limits students' opportunities to develop mathematical literacy as a transferable competence. Moreover, students' difficulties in geometry are often associated with limited access to instructional media that support visualization and conceptual exploration (Gurmu et al., 2024). Without appropriate instructional support, geometry learning remains abstract and inaccessible for many learners. These conditions highlight the need for pedagogical interventions that explicitly target representation skills. Therefore, investigating the role of instructional media in geometry learning becomes both timely and relevant.

From a literacy education perspective, mathematical representation is closely linked to students' capacity to make sense of mathematical texts, symbols, and visual information. Literacy-oriented learning views representation as a meaning-making process rather than a mechanical activity (Yüzlü & Mumford, 2025). Instructional media have been identified as powerful tools for supporting this process by bridging abstract concepts and concrete experiences (Li et al., 2023). Nevertheless, empirical evidence examining how instructional media contribute specifically to mathematical literacy development remains limited. Most existing studies focus on achievement outcomes rather than literacy-related competencies. This limitation suggests that the pedagogical value of instructional media has not been fully explored within a literacy framework. Addressing this issue is essential for advancing theory and practice in mathematics education. Accordingly, this study positions mathematical literacy as the central lens for examining geometry instruction.

The rationale for this study is grounded in the growing recognition that literacy should be embedded across all subject areas, including mathematics education. Mathematical literacy enables students to engage critically with quantitative information encountered in academic and real-world contexts (Geiger et al., 2023). Geometry learning provides rich opportunities for developing such

literacy because it involves interpreting diagrams, symbols, and spatial relationships. However, traditional instructional approaches often fail to capitalize on this potential due to limited use of interactive and representational learning tools. Instructional media offer an alternative pedagogical strategy by supporting students' visual and conceptual engagement with mathematical ideas (Nazari et al., 2024). When used effectively, these media can facilitate deeper understanding and active participation in learning. This pedagogical shift aligns with literacy-focused educational goals. Therefore, the study is designed to examine instructional media as a means of enhancing mathematical literacy rather than merely improving test performance.

Literature Review

Previous research has highlighted the positive impact of instructional innovations on students' mathematical literacy and representation skills. Pujiastuti & Haryadi, (2023) demonstrated that guided inquiry supported by augmented reality significantly enhanced students' mathematical literacy abilities. İlhan, (2021) reported that game-based and collaborative learning approaches improved students' visual mathematical literacy perceptions. Hetmanenko, (2024) found that digital technologies in geometry instruction contributed to improved mathematical proficiency. Setianingsih et al., (2025) emphasized the role of mathematical reading and writing abilities in supporting geometric reasoning. Taylor, (2018) explored how multimodal literacies facilitate the construction of mathematical arguments in geometry learning. Gao et al., (2023) showed that technology-supported instructional models enhance intuitive imagination in mathematics. These studies collectively suggest that instructional media can strengthen literacy-related competencies. However, they often emphasize technology rather than classroom-based instructional media.

Other studies have examined the integration of instructional media within broader educational frameworks. Saman et al., (2025) highlighted the value of interdisciplinary instructional design in enhancing learning engagement. Kovács & Wintsche, (2025) identified factors influencing teachers' adoption of interactive technologies in mathematics education. Fuste & Schmandt, (2019) demonstrated that augmented reality supports computational and spatial thinking. Solomon et al., (2020) provided foundational insights into technology-supported learning environments. Despite these contributions, limited attention has been given to how instructional media explicitly support mathematical representation as a core component of literacy. Most studies focus on technological novelty rather than pedagogical impact. This indicates a need for empirical research that examines instructional media through a literacy-oriented lens. The present study responds to this need by focusing on representation-based outcomes.

Although previous studies have explored the use of instructional media in mathematics education, several gaps remain evident. First, existing research predominantly emphasizes achievement scores rather than mathematical literacy development. Second, studies focusing on geometry instruction often neglect the role of representation as a literacy practice. Third, many investigations rely on digital or augmented reality tools, leaving classroom-based instructional media underexplored. Fourth, limited research employs quasi-experimental designs to compare literacy outcomes across instructional conditions. Fifth, the middle school context remains insufficiently examined despite its critical role in literacy development. These gaps suggest that the pedagogical potential of instructional media has not been fully realized. Addressing these gaps is necessary to strengthen evidence-based practices in literacy education. Consequently, this study seeks to fill these research voids.

The purpose of this study is to examine the effectiveness of geometry instructional media in developing students' mathematical literacy through enhanced representation skills. Specifically, the study investigates whether students who learn geometry with instructional media demonstrate higher levels of mathematical representation than those taught using conventional methods. It is hypothesized that instructional media facilitate students' ability to express mathematical ideas visually, symbolically, and contextually. The study also assumes that improved representation skills contribute to broader mathematical literacy development. By employing a quasi-experimental design, the research aims to provide empirical evidence supporting literacy-oriented instruction. The findings are expected to inform pedagogical practices in mathematics education. Additionally, the study seeks to contribute to theoretical discussions on literacy integration in mathematics learning. Ultimately, this research positions instructional media as a strategic tool for advancing mathematical literacy in middle school education.

METHOD

Research Design

This study employed a quasi-experimental research design with a pretest–posttest control group to examine the impact of geometry instructional media on students' mathematical literacy. Quasi-experimental design was selected because random assignment of participants was not feasible within the existing school structure, a condition commonly encountered in educational research settings (Creswell, 2014). The design enabled a systematic comparison between students who received instructional media-based geometry instruction and those who experienced conventional teaching methods. Mathematical literacy development was operationalized through students' mathematical representation skills as the primary outcome variable. Both groups were administered identical pretests and posttests to measure changes attributable to the instructional intervention. This approach ensured internal consistency while maintaining ecological validity in authentic classroom contexts. The instructional intervention was implemented over three structured learning sessions. Overall, the research design aligned with literacy-oriented educational inquiry by emphasizing learning processes and outcomes.

Participants

The participants of this study consisted of 60 eighth-grade students drawn from two middle schools with comparable academic characteristics. Participants were selected using purposive sampling to ensure similarity in curriculum implementation, school accreditation, and instructional quality. The students were divided into an experimental group and a control group, each comprising 30 learners. The experimental group received geometry instruction supported by instructional media, while the control group was taught using conventional instructional approaches. All participants had previously studied basic geometry concepts, ensuring equivalent baseline knowledge. Ethical considerations were addressed by obtaining permission from school authorities and informing participants about the research purpose. Students' identities were kept confidential throughout the study. The participant selection process supported the validity of comparative analysis in literacy-focused educational research.

Instrument

The primary instrument used in this study was a Mathematical Representation Ability Test designed to assess students' mathematical literacy in geometry contexts. The test measured students' ability to represent mathematical ideas through visual, symbolic, and verbal forms, which are core dimensions of mathematical literacy (NCTM, 2000). The instrument consisted of open-ended items requiring students to interpret diagrams, construct representations, and explain geometric concepts. Content validity was established through expert judgment by mathematics education specialists. A pilot study was conducted to examine the reliability of the instrument, resulting in a satisfactory internal consistency coefficient. A detailed scoring rubric was applied to ensure objective and consistent evaluation across representation indicators. The same instrument was administered as both pretest and posttest to measure learning gains. This instrument design ensured alignment with literacy-based assessment principles.

Data Analysis Plan

Data analysis was conducted using both descriptive and inferential statistical techniques to examine students' mathematical literacy development. Descriptive statistics, including means and standard deviations, were used to summarize pretest and posttest scores for both groups. Prior to hypothesis testing, normality and homogeneity assumptions were examined to ensure the suitability of parametric analysis (Field, 2018). Independent sample t-tests were employed to compare posttest scores between the experimental and control groups. This analysis aimed to determine whether geometry instructional media significantly influenced mathematical representation skills. Effect size calculations were included to assess the magnitude of the instructional impact, providing practical significance beyond statistical results. The significance level was set at 0.05 for all inferential analyses. This analytical approach strengthened the rigor and transparency of the research findings.

Additional Methodological Consideration

To further strengthen the study, the use of effect size reporting was incorporated to complement statistical significance testing. Effect size analysis is recommended in literacy and education research to provide meaningful interpretation of instructional impact (Cohen, 1988). This addition enhances the study's contribution by emphasizing educational relevance rather than reliance on p-values alone. It also aligns with international journal standards that prioritize both statistical and practical significance.

RESULTS AND DISCUSSION

Results

The results of this study present empirical evidence regarding the effect of geometry instructional media on students' mathematical literacy, particularly their representation skills. Prior to the intervention, both the experimental and control groups demonstrated comparable levels of mathematical representation ability, as indicated by similar pretest mean scores. After the instructional treatment, notable differences emerged between the two groups. The experimental group showed a substantial improvement in posttest scores compared to the control group. This increase suggests that instructional media contributed positively to students' ability to represent mathematical ideas. Statistical testing confirmed that the observed differences were significant.

These findings indicate that geometry instructional media play a meaningful role in literacy-oriented mathematics learning. A detailed summary of the descriptive statistics is presented in Table 1.

Table 1. Pretest and Posttest Results of Mathematical Representation Skills

Group	Test	Mean Score	Standard Deviation
Experimental	Pretest	35.97	10.23
Experimental	Posttest	75.06	4.68
Control	Pretest	37.94	8.75
Control	Posttest	70.26	4.98

Table 1 demonstrates that both groups experienced learning gains, yet the experimental group achieved higher improvement. The reduced standard deviation in the experimental group's posttest scores indicates more consistent learning outcomes. This consistency suggests that instructional media supported equitable understanding among students. Prior to inferential analysis, data were tested for normality and homogeneity to ensure statistical assumptions were met. The results confirmed that the data were normally distributed and homogeneous. Consequently, parametric tests were applied to evaluate group differences. The inferential analysis results are summarized in Table 2.

Table 2. Independent Sample t-Test Results

Data	Mean (Experimental)	Mean (Control)	t-value	p-value
Posttest	80.30	70.12	11.06	< 0.001

The t-test results indicate a statistically significant difference between the experimental and control groups. The p-value below 0.05 confirms that the improvement was not due to chance. These results provide strong empirical support for the effectiveness of instructional media in enhancing mathematical literacy. To further illustrate learning differences, a visual comparison of posttest scores is provided. The figure highlights score distribution patterns across groups. This visualization reinforces the quantitative findings. The figure is presented as Figure 1.

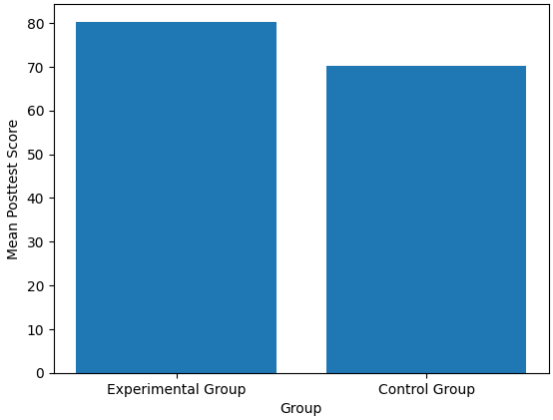

Figure 1. Comparison of Posttest Mean Scores Between Groups

Discussion

The findings of this study demonstrate that geometry instructional media significantly enhance students' mathematical literacy through improved representation skills. Students exposed to instructional media were better able to express geometric ideas visually, symbolically, and verbally. This outcome supports the view that mathematical literacy extends beyond procedural competence

to include meaning-making processes (NCTM, 2000). The results align with previous research emphasizing the role of representation in mathematical understanding (Taylor, 2018). Instructional media facilitated students' engagement with abstract concepts by providing concrete referents. This engagement enabled learners to construct deeper conceptual connections. Similar improvements have been reported in studies using interactive learning approaches (Ilhan, 2021). Thus, instructional media function as effective literacy-support tools in geometry learning.

The significant improvement observed in the experimental group confirms that representation-based instruction strengthens literacy-oriented learning outcomes. These findings are consistent with research showing that visual and multimodal representations enhance mathematical reasoning (Setianingsih et al., 2025). Instructional media allowed students to explore geometric relationships dynamically, fostering interpretive and analytical skills. This aligns with Pujiastuti and Haryadi's (2023) findings on guided inquiry and literacy development. Moreover, instructional media reduced cognitive load by externalizing abstract information. This reduction supported students' comprehension and explanation abilities. Hetmanenko (2024) similarly noted the effectiveness of visual technologies in geometry learning. Collectively, these results reinforce the pedagogical value of instructional media.

From a literacy education perspective, the findings highlight the importance of integrating representational practices into mathematics instruction. Mathematical literacy involves interpreting mathematical texts, symbols, and visual information coherently (Taylor, 2018). Instructional media encouraged students to engage in these literacy practices actively. This engagement aligns with sociocultural views of learning that emphasize interaction and mediation (Vygotsky, 1978). The consistency of learning gains suggests that instructional media promote inclusive learning opportunities. Students with varying initial abilities benefited from the intervention. Such outcomes are crucial for literacy-oriented classrooms. Previous studies also emphasize equitable learning through interactive instruction (Ilhan, 2021). Therefore, instructional media contribute to both effectiveness and equity.

The study also contributes to the broader discourse on instructional innovation in mathematics education. While many studies focus on advanced digital technologies, this research demonstrates that classroom-based instructional media remain pedagogically powerful. This finding echoes Kovács and Wintsche's (2025) assertion that effective instruction depends on pedagogical design rather than technological sophistication. Instructional media served as mediational tools that supported meaning construction. Gao et al. (2023) similarly reported that instructional models enhance intuitive understanding. These results suggest that literacy-oriented instruction can be achieved through accessible instructional strategies. Such strategies are particularly relevant in diverse educational contexts. Consequently, this study extends existing literature by emphasizing pedagogical function over technological novelty.

Overall, the discussion underscores the alignment between instructional media use and literacy-focused education goals. The findings support the integration of instructional media as a deliberate strategy for enhancing mathematical literacy. This integration addresses persistent challenges in geometry learning. The study confirms that representation is central to meaningful mathematical understanding (NCTM, 2000). Instructional media operationalize representation in tangible ways. By fostering interpretive and communicative skills, these media support holistic

literacy development. The results affirm the relevance of literacy-oriented mathematics instruction. Thus, the study contributes both empirical evidence and pedagogical insights.

Implications

The findings of this study have important implications for mathematics education practice and policy. Instructional media should be viewed as essential tools for developing mathematical literacy rather than supplementary resources. Teachers are encouraged to integrate representation-based instructional media into geometry lessons. Such integration supports students' ability to interpret and communicate mathematical ideas effectively. Curriculum designers may consider embedding instructional media within literacy-oriented learning frameworks. This approach aligns with international standards emphasizing literacy across disciplines (NCTM, 2000). Teacher training programs should also emphasize representation-focused pedagogy. These implications support more meaningful and inclusive mathematics instruction.

Limitations

Despite its contributions, this study has several limitations that should be acknowledged. The sample size was limited to two middle schools, which may affect generalizability. The intervention duration was relatively short, focusing on three instructional sessions. Longer interventions may yield deeper insights into literacy development. The study concentrated on representation skills as a proxy for mathematical literacy. Other literacy dimensions, such as reasoning and argumentation, were not examined. Additionally, the study relied on quantitative measures without qualitative data. Classroom observations could have enriched interpretation. These limitations suggest caution in interpreting the findings.

Suggestions

Future research should expand the scope of investigation by involving more diverse educational settings. Longitudinal studies are recommended to examine sustained impacts of instructional media on mathematical literacy. Researchers may also explore qualitative methods to capture students' literacy practices more comprehensively. Investigating teacher perspectives on instructional media use could provide valuable insights. Further studies might examine other literacy components such as mathematical communication and reasoning. Comparative studies across grade levels are also suggested. Integrating interdisciplinary literacy frameworks could strengthen future research. These directions would advance understanding of literacy-oriented mathematics education.

CONCLUSION

This study demonstrates that geometry instructional media play a significant role in developing students' mathematical literacy, particularly in enhancing mathematical representation skills. Students who engaged in media-supported geometry instruction showed stronger abilities to interpret, express, and communicate mathematical ideas across visual, symbolic, and verbal forms. These findings confirm that mathematical literacy is not merely a procedural outcome but a meaning-making process supported by appropriate pedagogical tools. Instructional media functioned as mediational resources that bridged abstract geometric concepts with concrete learning experiences. The results highlight the importance of integrating representation-based instruction into literacy-oriented mathematics education. From an educational perspective, the study reinforces the

alignment between instructional design and literacy development goals. The findings contribute empirical evidence to the growing discourse on literacy integration in mathematics classrooms. Overall, this research supports the strategic use of instructional media as an effective approach to fostering meaningful and inclusive mathematical literacy in middle school education.

AUTHOR CONTRIBUTION STATEMENT

Wahyu Kusumaningtyas was solely responsible for the conceptualization and design of the study. The author conducted the data collection, implemented the instructional intervention, and managed the research process. Data analysis and interpretation of the results were carried out independently by the author. The author also prepared the original draft of the manuscript and performed all revisions. All sections of the article were written and reviewed by the author. The author approved the final version of the manuscript for publication.

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