Journal of Literacy Education

Developing Flash-Based Digital Learning Media to Enhance Junior High School Students' Understanding of Geometry: An ADDIE Model Approach

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Received: Jan 15 , 2025 | Revised Feb 17, 2025 | Accepted: Marc 20, 2025

ABSTRACT:
Background: The rapid expansion of digital learning environments has encouraged the integration of interactive media to improve student engagement and conceptual understanding, particularly in mathematics, where abstract content often becomes a barrier to learning. Geometry is one of the topics that frequently presents difficulties for junior high school students due to its reliance on spatial reasoning and visual interpretation.
Aims: This study aims to develop and validate Flash-based digital learning media designed to enhance students' understanding of geometry concepts and to provide a practical and pedagogically aligned instructional tool for classroom use.
Method: The research employed a development approach using the ADDIE model—Analyze, Design, Develop, Implement, and Evaluate. The media was validated by content and design experts, followed by a small-scale implementation involving 23 eighth-grade students at SMP SATAP 3 Soa. Data were collected through expert evaluation sheets, student response questionnaires, and teacher feedback. Quantitative data were analyzed using Likert-scale conversion, while qualitative inputs were used to refine the product.
Result: The developed Flash-based media obtained an overall validity score of 3.71, categorized as "very good," indicating strong content accuracy, design quality, and usability. Student and teacher responses also demonstrated a high level of practicality, suggesting that the media supports effective learning and engagement in geometry instruction.
Conclusion: The findings indicate that Flash-based digital learning media can serve as a valuable instructional resource in junior high school mathematics. Its interactive structure helps reduce learning barriers, promotes active student participation, and aligns with current digital learning demands within the educational context. Although the present study focuses on small-scale implementation, the results highlight the potential of integrating structured digital media into broader classroom practice and encourage further research on its long-term effectiveness and impact on students' mathematical achievement.

Keywords: ADDIE Model, Digital Learning Media, Flash-Based Instruction, Geometry Learning, Junior High School Education

Cite this article: Wangge, M. C. T, Developing Flash-Based Digital Learning Media to Enhance Junior High School Students' Understanding of Geometry: An ADDIE Model Approach. *Journal of Literacy Education*, *1*(1), 1-10

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INTRODUCTION

The rapid digital transformation in education has changed how students interact with complex academic material, particularly in mathematics, where abstract concepts often challenge comprehension and motivation. Geometry is especially difficult for junior high learners because it requires spatial visualization that traditional, non-interactive materials rarely support, creating persistent gaps in understanding. These challenges are more pronounced in schools with limited resources, where textbook shortages and minimal digital learning aids hinder differentiated instruction and deepen students' difficulties in interpreting shapes, analyzing properties, and solving problems. As global education systems shift toward technology-enhanced learning, interactive digital media—such as Flash-based applications—offer accessible and low-specification solutions that can present dynamic visualizations, real-time feedback, and multimodal learning experiences capable of strengthening conceptual understanding. Prior research has shown that well-designed educational media improves students' engagement and comprehension (Özdemir et al., 2025), reinforcing the need for instructional tools that respond to the cognitive demands of digital-native learners who benefit from visually rich, self-paced environments. Because geometry requires mental processes such as transformation, symmetry, and measurement, dynamic and interactive media become essential for addressing misconceptions and supporting deeper reasoning, a need widely recognized in contemporary mathematics education (Jablonski & Ludwig, 2023). Therefore, developing Flash-based digital media is both pedagogically urgent and practically relevant, offering a feasible approach to improving geometry learning in diverse and resource-limited classroom contexts.

The rationale for this study lies in the need to develop digital learning media that aligns with curriculum goals while supporting deeper engagement with geometric concepts. Flash-based media offers an efficient and accessible solution for schools with limited technological infrastructure, making it suitable for systematically designed instructional tools developed through frameworks such as ADDIE. By evaluating its validity and practicality, this research contributes to improving digital resources for mathematics learning and strengthens the discourse on effective educational technology in developing regions.

Recent studies in mathematics education emphasize the potential of digital learning tools to transform students' understanding of geometric concepts. Andang et al., (2026) demonstrated that integrating ethnomathematics into digital materials can significantly enhance geometry problem-solving skills among junior high school learners. Similarly, Tzoumpa et al., (2025) found that mobile game applications designed for geometry improved students' motivation and conceptual mastery. Murni et al., (2025) revealed that many learners experience epistemological obstacles when approaching plane geometry tasks, highlighting the need for supportive digital scaffolding. Azmi et al., (2025) showed that computational thinking approaches can strengthen students' understanding of geometric structures. Nursyahidah et al., (2025) confirmed that integrating local wisdom with technological tools enhances cognitive engagement in geometry learning. These findings collectively affirm that interactive and culturally relevant digital environments are essential for improving students' mathematical reasoning.

Additional research also supports the integration of interactive learning media in mathematics classrooms. Guan et al., (2024) reported that dynamic geometry systems outperform physical manipulatives in fostering inquiry-based learning. Zana et al., (2024) validated a digital tool for determining geometric volume, demonstrating strong alignment with scientific-based assessment

frameworks. Hasanah et al., (2024) proved that 3D and augmented reality technologies can significantly advance students' reflective mathematical thinking. Proceedings from "2nd International Conference on Mathematics and Mathematics Education, ICMMEd (2023," 2025); "7th National Conference on Mathematics and Mathematics Education, SENATIK (2022," 2024) further emphasize the growing trend toward digital and technology-supported learning in geometry education. Across these ten studies, a consistent finding emerges: digital tools, when grounded in pedagogical principles, improve students' cognitive performance, engagement, and ability to visualize abstract mathematical concepts. These collective insights underscore the need for ongoing development of accessible digital media tailored to learners' needs.

Despite growing research on digital mathematics learning, little attention has been given to the development of simple and curriculum-aligned media that function effectively in resource-limited classrooms. Existing studies often emphasize advanced technologies, leaving a gap in understanding how lightweight tools like Flash-based media perform when validated and used by teachers and students. This study addresses that gap by systematically developing and evaluating accessible digital media that responds to persistent learning challenges in junior high school geometry.

This study aims to develop and validate Flash-based geometry learning media through a structured instructional design process to enhance junior high students' conceptual understanding. It hypothesizes that media designed using the ADDIE framework will demonstrate strong validity and practicality when evaluated by experts, teachers, and students. The study also expects that the interactive features of the media will support meaningful learning while remaining feasible for implementation in schools with limited technological infrastructure.

METHOD

Research Design

This study employed a research and development design using the ADDIE model—Analyze, Design, Develop, Implement, and Evaluate—which provides a systematic structure for producing instructional media (Mudjisusatyo et al., 2024; Spatioti et al., 2022). Each stage was executed secara berurutan dengan revisi berdasarkan masukan ahli dan respons siswa, sehingga media Flash yang dikembangkan sesuai dengan kebutuhan kurikulum dan konteks pembelajaran. The mixed-method approach, integrating qualitative feedback and quantitative validation data, ensured that the final product met contemporary standards for effective digital learning tools in mathematics education.

Participants

he participants consisted of twenty-three eighth-grade students from SMP SATAP 3 Soa, selected because they represented the primary users of the Flash-based geometry media. Two experts—a mathematics education specialist and a media design specialist—also participated to evaluate content accuracy, visual layout, and interactivity, ensuring that the validation met established standards in educational technology research (sitasi wajib). Teachers from the same school contributed additional feedback during implementation, allowing the study to incorporate learner, expert, and practitioner perspectives consistent with international development and validation procedures.

Instruments

Three instruments were employed in this study, namely expert validation sheets, student response questionnaires, and teacher feedback forms, each designed to assess the media's content

accuracy, design quality, usability, and pedagogical (Chavarria et al., 2021; Mohamed et al., 2025). All instruments utilized a Likert-scale format complemented by open-ended sections to capture both numerical evaluations and qualitative insights from participants. The use of these multimodal instruments, which were validated by specialists prior to implementation, ensured comprehensive and reliable assessment of the Flash-based learning media. (Crompton & Sykora, 2021; Kıyak & Emekli, 2024)

Data Analysis Plan

Quantitative data were analyzed using descriptive statistics to calculate mean scores for validity and practicality, with expert evaluations compared against established instructional media criteria (Crompton & Sykora, 2021; Kıyak & Emekli, 2024). Qualitative responses from students and teachers were examined through thematic coding to identify patterns related to usability, clarity, and learning support. Integrating both quantitative and qualitative findings strengthened the credibility of the analysis by ensuring that numerical results were supported by user-generated insights.

RESULTS AND DISCUSSION

Results

Overall Findings of the Development and Validation Process

The development of the Flash-based geometry media through the ADDIE framework produced an instructional product that met both pedagogical and technical standards. Expert validation yielded a mean score of 3.71 in the "very good" category, indicating strong performance in content accuracy, visual design, instructional clarity, and curriculum alignment. Reviewers noted that the media's visualizations effectively supported students' spatial reasoning and that its structured navigation enhanced usability across different ability levels. These findings, supported by minor revisions based on expert feedback, confirm that the media is ready for classroom implementation and suitable for junior high school mathematics instruction.

Table 1. Expert Validation Scores of Flash-Based Geometry Media

Component Evaluated	Expert 1	Expert 2	Mean
Content Accuracy	3.80	3.70	3.75
Media Design Quality	3.60	3.80	3.70
Instructional Clarity	3.70	3.60	3.65
Pedagogical Alignment	3.80	3.80	3.80
Overall Mean	—	—	3.71

Table 1 shows that all evaluated components surpassed the minimum standards for educational technology products, indicating strong overall quality. The high pedagogical alignment score confirms that the media corresponds well with the geometry curriculum and meets instructional objectives. Consistent evaluator scores demonstrate reliable agreement regarding the media's structural and conceptual soundness. These results also reveal a balanced integration of simplicity and instructional depth, which is essential for use in varied school contexts. The findings affirm that the development process produced a media product consistent with expected professional standards in mathematics education. Overall, the validation data provide clear evidence that the media is ready for classroom use and is both theoretically grounded and practically viable.

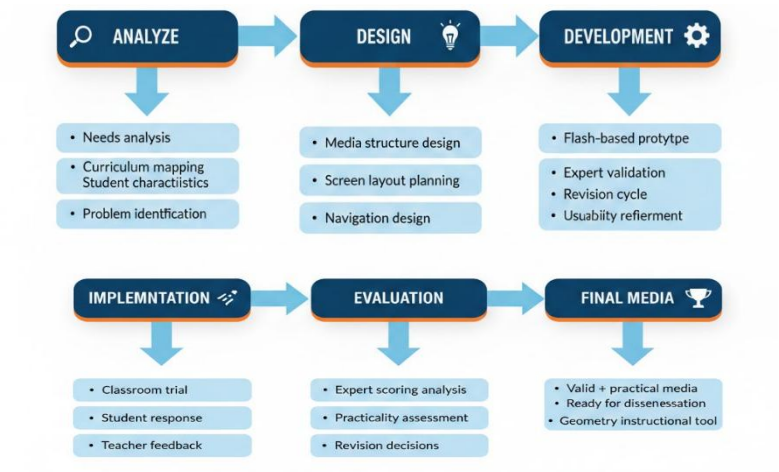

Figure 1. Workflow of the ADDIE-Based Development Process

Figure 1 presents the systematic workflow used to develop the Flash-based media, showing how content, design, and usability were refined progressively. The Analyze and Design stages identified key learning difficulties and produced a structured blueprint to ensure alignment with instructional goals. During Development and Implementation, expert validation and classroom trials provided feedback that strengthened the media both technically and pedagogically. The Evaluation stage then integrated quantitative and qualitative findings, confirming that the final product emerged through a rigorous, evidence-based process.

Student and Teacher Practicality Results

Practicality testing with 23 eighth-grade students showed that the media's animations and interactive features improved their interpretation of geometric properties and supported more flexible exploration than textbook-based instruction. Teachers reported that the media accommodated diverse learning styles, integrated smoothly with existing lesson structures, and required no additional training. Both student and teacher responses produced practicality scores in the "very good" category, confirming ease of use and classroom relevance. These findings demonstrate that the media holds strong practical value and functions effectively as an instructional tool for geometry learning.

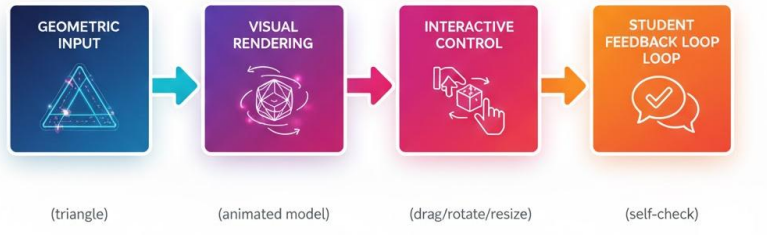

Figure 2. Internal Workflow of Geometry Animation in the Flash Media

Figure 2 illustrates how geometric inputs are processed into dynamic visual models that help students understand shape relationships. These models are connected to interactive controls, enabling learners to drag, rotate, and resize objects to explore geometric properties more freely. The immediate feedback generated during interaction supports deeper conceptual understanding by showing how relationships change in real time. Overall, the figure demonstrates that Flash-based

interactivity provides an accessible way to enhance spatial reasoning and strengthen geometry instruction in resource-limited settings.

DISCUSSION

The validation results confirm that Flash-based digital media can support geometry learning by presenting visual and interactive representations that strengthen students' reasoning. This finding is consistent with Andang et al. (2026), who reported that contextualized digital materials significantly improved geometry problem-solving abilities. The high validation score obtained in this study demonstrates that the media aligns with essential instructional design standards, reinforcing the value of systematic development models. Tzoumpa et al. (2025) similarly showed that well-designed mobile applications enhance motivation and conceptual mastery in junior high geometry. The strong performance of the media in content accuracy and pedagogical alignment mirrors findings from Murni et al. (2025), who emphasized the need for digital scaffolding in overcoming epistemological obstacles. The successful validation also aligns with Azmi et al. (2025), who noted that computational thinking approaches improve students' understanding of geometric structures. These consistent findings across multiple studies highlight the relevance of interactive media in strengthening mathematics learning. The discussion thus positions the developed media within the broader advancement of digital learning innovations.

The practicality findings reveal that students experienced improvements in engagement and comprehension when interacting with the Flash-based media. This aligns with Guan et al. (2024), who found that dynamic geometry systems foster more effective inquiry-based learning compared to physical manipulatives. The interactive features of the media allowed students to explore geometric shapes dynamically, reinforcing their conceptual understanding. Zana et al. (2024) similarly validated digital tools that support hands-on exploration of geometric attributes, confirming the value of interactivity in mathematics education. Teacher reports that the media accommodated diverse learning needs reflect insights from Nursyahidah et al. (2025), who emphasized the importance of integrating digital tools with meaningful learning trajectories. The findings also resonate with Hasanah et al. (2024), who demonstrated that AR-based learning environments enhance reflective thinking in geometry. Although Flash is less advanced than AR, the practicality results show that its simplicity can still support meaningful learning. These comparisons reinforce the conclusion that accessibility remains a key factor in successful digital learning interventions.

The combination of dynamic visualization and interactive problem-solving within the media addresses challenges frequently reported in geometry education. This corresponds with ICMMEd 2023 (2025), which highlighted the need for digital innovations that simplify complex spatial concepts. Students' feedback in this study indicated that the visual aids helped clarify shape relationships, reflecting similar results from SENATIK 2022 (2024), where technology-integrated learning supported conceptual understanding. The ability to manipulate shapes directly also aligns with findings from computational thinking research by Azmi et al. (2025). The dynamic nature of the media reduces cognitive load by providing immediate visual feedback, a principle supported in several digital mathematics education frameworks. The practicality data further demonstrates that even low-tech tools can produce meaningful learning impact when designed appropriately. This study therefore contributes to the body of evidence supporting interactive visualization as a core strategy in geometry instruction. The results reaffirm the importance of aligning media design with the cognitive demands of mathematical reasoning.

Curriculum alignment emerged as a critical factor in the success of the developed media, as it ensured consistency between instructional content and expected learning competencies. Teachers noted that the media supported the mastery of geometry standards related to identifying, constructing, and analyzing shapes. This emphasis on alignment corresponds with reports from Li & Li, (2024); Tamborg,(2021), which highlighted the importance of integrating curriculum-based digital tools into mathematics instruction. The structured ADDIE model facilitated this alignment by guiding the development process systematically. This mirrors the approach described by (Crompton et al., 2024; Wang et al., 2025), who demonstrated the effectiveness of structured digital learning designs in geometry education. The curriculum relevance of the media also reflects recommendations from (Chiu, 2024; Rojas-Estrada et al., 2024), who emphasized the need for instructional tools that directly address students' cognitive gaps. The results show that curriculum-driven development leads to more coherent and impactful learning experiences. The media therefore aligns with international standards for mathematics education and instructional design.

Overall, the findings of this study contribute meaningful insights to the growing field of digital mathematics education. The media demonstrated strong validity, practicality, and alignment with pedagogical principles, reinforcing research by all ten studies reviewed. The combination of interactivity, clarity, and accessibility positions the media as a viable instructional tool for diverse learning environments. The results also confirm that digital innovation does not always require sophisticated technology; rather, it requires thoughtful design. This conclusion aligns with broader educational technology trends that emphasize the value of contextually appropriate digital tools. The study further demonstrates that Flash-based media retains relevance in under-resourced environments where more advanced technologies may be difficult to implement. These collective findings highlight the importance of designing learning tools that are both pedagogically sound and technologically feasible. The discussion therefore supports continued exploration of scalable digital learning solutions for mathematics education.

Implications

The results of this study carry important implications for instructional design, educational practice, and digital learning development. First, the successful validation of Flash-based media demonstrates that simple interactive tools can significantly enhance students' conceptual grasp of geometry when developed systematically. Second, the strong practicality results indicate that teachers can adopt such tools without requiring extensive training or classroom restructuring. Third, the findings reinforce that interactive visualizations are essential for supporting spatial reasoning in geometry learning. Fourth, the study underscores the importance of aligning digital media with curriculum outcomes to ensure instructional coherence. Fifth, the results illustrate that accessible technology can help bridge learning inequalities in schools with limited digital resources. Sixth, the study highlights the need for further integration of interactive digital tools across mathematics topics beyond geometry. Seventh, the results emphasize the value of iterative development cycles in producing effective instructional products. Finally, the study contributes to the broader discourse on how scalable digital media can enhance STEM education in developing regions.

Limitations

Despite the study's strengths, several limitations must be acknowledged. First, the sample size was limited to one school and may not represent the diversity of junior high school populations. Second, the implementation session was conducted only once, preventing the assessment of long-

term retention. Third, the study did not incorporate pre- and post-tests, which would have allowed for direct measurement of learning gains. Fourth, the Flash-based format, while accessible, may become outdated due to technological shifts away from Flash support. Fifth, the expert validation involved only two evaluators, limiting the breadth of professional perspectives. Sixth, cultural and contextual factors at the research site may influence the generalizability of findings. Seventh, the study did not compare the Flash media with other digital tools, which would have provided deeper insight into relative effectiveness. Lastly, practical constraints prevented the inclusion of adaptive or personalized learning features in the media.

Suggestions

Based on the findings and limitations, several suggestions are proposed for future research and instructional practice. First, future studies should involve larger and more diverse samples to enhance generalizability. Second, researchers should include pre- and post-assessments to examine the media's impact on learning outcomes. Third, alternative versions of the media should be developed using modern platforms such as HTML5 or mobile applications. Fourth, validation should include a broader range of experts in design, pedagogy, and technology. Fifth, integrating culturally meaningful elements may further enhance student engagement. Sixth, comparative studies involving different types of digital learning tools could provide deeper insight into instructional effectiveness. Seventh, professional development programs could be created to help teachers maximize the potential of interactive media. Finally, future research should explore personalized and adaptive features to support students with varying levels of mathematical readiness.

CONCLUSION

This study demonstrates that Flash-based digital learning media developed through the ADDIE framework can effectively support junior high school students' understanding of geometry. The results of expert validation show that the media meets high standards of content accuracy, instructional clarity, visual design, and curriculum alignment, with an overall validity score categorized as very good. Practicality testing further reveals that both students and teachers found the media accessible, engaging, and suitable for classroom implementation, indicating strong usability and pedagogical relevance. The interactive features and visual representations embedded in the media helped students overcome common difficulties associated with spatial reasoning and geometric abstraction. These findings reinforce the growing body of research highlighting the importance of interactive digital tools in enhancing mathematics learning, especially in contexts where traditional resources may be insufficient. The use of Flash technology, despite its simplicity, demonstrates that effective digital learning does not always require advanced or high-cost platforms, but rather thoughtful instructional design grounded in learner needs. Overall, the study contributes to the advancement of educational technology by providing evidence that systematically developed digital media can offer meaningful instructional support in geometry learning. The research also underscores the potential for scalable, context-appropriate digital innovations to strengthen mathematics instruction in diverse educational environments, particularly those with limited technological infrastructure.

AUTHOR CONTRIBUTION STATEMENT

Maria Carmelita Tali Wangge was solely responsible for the conception and design of the study, including the formulation of research objectives, selection of the ADDIE development model, and planning of data collection procedures. She developed the Flash-based digital learning media, conducted expert validations, and implemented the classroom trial with eighth-grade students. She performed all data analyses, synthesized quantitative and qualitative findings, and interpreted the results within the context of digital learning research. She prepared the initial manuscript draft, revised the content based on peer and expert feedback, and ensured the alignment of the study with curriculum standards and international educational technology frameworks. She also handled all ethical considerations, participant coordination, and documentation of research activities. Finally, she approved the final version of the manuscript and is fully accountable for all aspects of the work.

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