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Research Paper

Designing a STEAM-Oriented Interactive Learning Environment Using Articulate Storyline 3 to Support Elementary Mathematics Learning

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Abstract

Developing students' mathematical understanding at the elementary level remains a persistent challenge, particularly in learning contexts that rely heavily on conventional and minimally interactive instructional media. This study reports the development and evaluation of COMATH (Confident in Mathematics), an interactive learning medium created using Articulate Storyline 3 and informed by a STEAM (Science, Technology, Engineering, Arts, and Mathematics) pedagogical framework. A Research and Development approach was employed using the ADDIE instructional design model. The media was implemented in fourth-grade mathematics instruction focusing on plane geometry at an Indonesian elementary school. Data were obtained through expert validation, user trials, and a pre-test–post-test design involving 20 students. The expert review indicated that the media demonstrated high feasibility, with an overall score of 92.75%. Quantitative analysis revealed a substantial improvement in students' learning outcomes, with an average score increase of 34.96% and an N-gain value of 78.6%, indicating high effectiveness. Statistical testing confirmed a significant difference between pre-test and post-test results ($t = -24.965$, $p < 0.05$). These findings suggest that integrating STEAM principles into an interactive multimedia learning environment can effectively enhance elementary students' mathematical understanding. The study underscores the potential of Articulate Storyline 3 as a practical authoring tool for designing engaging, learner-centered mathematics instruction aligned with 21st-century educational goals.

Keywords: *interactive multimedia learning; Articulate Storyline 3; STEAM pedagogy; elementary mathematics; educational technology*

INTRODUCTION

Mathematics plays a central role in fostering logical reasoning, analytical thinking, and problem-solving abilities that are essential for learners' academic development and everyday life (Ausubel, 1968; Wahono et al., 2020). However, at the elementary level, students are often required to engage with abstract mathematical concepts. At the same time, their cognitive development remains concrete mainly, which may hinder meaningful learning if instructional support is limited. As a result, mathematics is frequently perceived by young learners as difficult and disengaging, particularly when instruction relies heavily on conventional, teacher-centered approaches (Zubaidah, 2018).

In Indonesia, these challenges are reflected in students' performance on international assessments. According to the Programme for International Student Assessment (PISA) 2022, Indonesian students scored an average of 366 in mathematics literacy, which is considerably below the OECD average of 498 (OECD, 2023). This gap indicates persistent systemic issues in mathematics instruction, particularly in fostering conceptual understanding and problem-solving skills rather than relying solely on procedural knowledge.

At the classroom level, similar issues were identified at SD Putra 1, an elementary school in East Jakarta. School records showed a decline in fourth-grade students' mathematics achievement,

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particularly in geometry. Classroom observations and interviews revealed that instructional practices relied heavily on static presentation media, such as slide-based lectures, which offered limited opportunities for interaction, exploration, or conceptual visualization. Consequently, students often perceived mathematics learning as monotonous and cognitively demanding.

Educational research consistently demonstrates that learning environments that actively engage students through interactive and multisensory experiences are more effective than passive instructional approaches. Well-designed multimedia learning environments can support students in constructing mathematical meaning by integrating visual representations, verbal explanations, and immediate feedback. In this regard, interactive learning media have become increasingly important in addressing conceptual difficulties in mathematics education.

In response to these challenges, contemporary education increasingly emphasizes interdisciplinary learning approaches, particularly through the STEAM framework. STEAM integrates science, technology, engineering, arts, and mathematics to promote creativity, critical thinking, and problem-solving through authentic learning experiences (Becker & Park, 2011; Perignat & Katz-Buonincontro, 2019). By connecting mathematical concepts to real-world applications and creative activities, STEAM-based instruction enables students to construct knowledge in a more meaningful, context-rich manner (Wahyuningsih et al., 2020).

Although previous studies have separately documented the effectiveness of interactive multimedia learning and STEAM-based instruction, research that systematically integrates both approaches in elementary mathematics contexts remains limited. To address this gap, the present study aims to develop and evaluate an interactive STEAM-oriented learning medium in Articulate Storyline 3 to support fourth-grade students' understanding of plane geometry.

Research Gap and Contribution

Existing research on educational technology has widely acknowledged the positive impact of interactive multimedia on student engagement and learning outcomes. Similarly, studies on STEAM education have highlighted its potential to foster interdisciplinary thinking and problem-solving skills. However, much of the existing literature treats these two dimensions—technology integration and STEAM pedagogy—as separate strands of inquiry.

Few studies have explicitly examined how STEAM principles can be embedded within interactive multimedia environments in elementary mathematics learning. Moreover, prior research often focuses on secondary or higher education contexts, leaving elementary-level applications underexplored. In addition, many studies emphasize learning outcomes without sufficiently describing the instructional design process that underpins the effectiveness of the developed media.

This study contributes to the literature in three ways. First, it presents a systematic development process for integrating STEAM pedagogy into an interactive multimedia learning environment using Articulate Storyline 3. Second, it provides empirical evidence of the feasibility and effectiveness of such media in an elementary mathematics context, specifically in learning plane geometry. Third, the study offers a practical example of how interdisciplinary and technology-enhanced approaches can be operationalized within the constraints of real classroom settings in developing educational contexts.

LITERATURE REVIEW

Interactive Multimedia and Mathematics Learning

Interactive multimedia learning environments combine text, images, animation, audio, and user interaction to support active learning processes. According to the cognitive theory of multimedia learning, students learn more effectively when verbal and visual information are

presented in an integrated manner that manages cognitive load appropriately (Mayer, 2020). In mathematics education, interactive multimedia has been shown to support students' conceptual understanding by facilitating visualization of abstract concepts, such as geometric shapes and spatial relationships, which are often challenging for elementary learners (Rianto, 2020; Indriani et al., 2021).

Previous studies have shown that interactive multimedia learning media can enhance students' motivation and conceptual understanding. Research involving Articulate Storyline-based instructional media has reported positive effects on students' learning outcomes, particularly when interactive features are aligned with instructional objectives and learner characteristics.

STEAM Pedagogy in Elementary Education

STEAM education extends the traditional STEM framework by incorporating artistic and creative dimensions, emphasizing holistic problem-solving and learner-centered inquiry. In elementary education, STEAM-based learning has been associated with the development of critical thinking, creativity, collaboration, and communication skills. By integrating multiple disciplines, STEAM enables students to approach mathematical problems from diverse perspectives and apply their knowledge in meaningful contexts.

STEAM-oriented instruction is closely aligned with constructivist learning theories, which emphasize that knowledge is actively constructed through experience and interaction. Project-based and design-based activities commonly used in STEAM learning encourage students to explore, experiment, and reflect, thereby deepening their conceptual understanding.

Articulate Storyline 3 as an Instructional Design Tool

Articulate Storyline 3 is an e-learning authoring tool that enables educators to develop interactive learning materials without requiring advanced programming skills. Its features, including branching scenarios, interactive quizzes, animations, and learner-controlled navigation, enable instructional designers to create engaging, learner-centered environments (Indriani et al., 2021; Firstanianta et al., 2023). Previous studies have reported that Storyline-based learning media can positively influence students' motivation and learning outcomes when pedagogical principles are effectively embedded in the design (Rianto, 2020).

However, the educational effectiveness of such tools depends primarily on how pedagogical principles are embedded in their design. Integrating STEAM principles into Articulate Storyline-based media represents a promising approach for enhancing both engagement and learning outcomes, particularly in mathematics education.

Instructional Design, Cognitive Alignment, and STEAM Creativity

Instructional design in elementary mathematics learning should be grounded in a clear alignment between learning objectives, cognitive processes, and instructional strategies. Anderson and Krathwohl (2010) emphasize that effective learning design requires deliberate alignment between intended learning outcomes and the cognitive demands placed on learners. In the context of elementary mathematics, this alignment is particularly critical, as students are still developing foundational cognitive structures and often struggle with abstract representations. Interactive multimedia environments can support this alignment by providing concrete visualizations and structured learning pathways that correspond to learners' cognitive readiness.

Within STEAM-oriented learning, instructional design also plays a crucial role in fostering creativity and interdisciplinary thinking. Henriksen et al. (2020) argue that STEAM education should be intentionally designed to support creative cognition by integrating disciplinary knowledge with opportunities for exploration, experimentation, and reflection. In elementary

mathematics, this perspective encourages the use of visual, artistic, and technological elements to help students approach mathematical problems from multiple perspectives. Such design principles align well with interactive multimedia environments, where learners can engage with content dynamically rather than through static representations.

Previous studies have also highlighted the effectiveness of multimedia-based learning media developed using authoring tools such as Articulate Storyline. Ahsan (2023) reported that the use of Storyline-based learning media positively influenced students' learning outcomes and learning interest when interactive features were aligned with instructional objectives. These findings suggest that the pedagogical effectiveness of multimedia learning environments depends not merely on technological features, but on how those features are designed to support cognitive and motivational processes.

Taken together, these studies indicate that the integration of STEAM pedagogy, cognitive alignment, and instructional design principles forms a strong theoretical foundation for the development of interactive multimedia learning environments. This foundation informed the design decisions in the present study, particularly in structuring learning activities, interactive tasks, and assessment components within the developed media.

Multimedia Learning, Cognitive Load, and Elementary Learners

In elementary mathematics education, the effectiveness of instructional media is closely related to how learning materials align with students' cognitive development. Young learners are generally characterized by concrete operational thinking, which requires instructional support that emphasizes visualization, manipulation, and contextual learning experiences. When mathematical instruction relies heavily on symbolic representation without sufficient scaffolding, students often experience cognitive overload, resulting in reduced comprehension and engagement.

The cognitive theory of multimedia learning provides a strong theoretical foundation for addressing this challenge. According to Mayer (2020), meaningful learning occurs when learners are able to actively select, organize, and integrate verbal and visual information within their working memory. Well-designed multimedia learning environments can reduce extraneous cognitive load while supporting germane cognitive processing, enabling students to construct coherent mental representations of abstract concepts. In mathematics learning, particularly geometry, this approach is highly relevant because visual-spatial reasoning plays a central role in conceptual understanding.

Interactive multimedia environments allow instructional designers to present mathematical content in multiple representational forms, including diagrams, animations, simulations, and symbolic expressions. This multimodal representation supports students in transitioning from concrete experiences to abstract reasoning. Research has shown that such environments are particularly effective for elementary learners, as they facilitate conceptual visualization and provide opportunities for exploration and immediate feedback.

Beyond cognitive considerations, learner motivation is a critical factor influencing the effectiveness of multimedia learning. Students' perceptions of learning media, including its usability, visual appeal, and interactivity, significantly affect their willingness to engage with learning tasks. When learners perceive instructional media as engaging and accessible, they are more likely to sustain attention and persist in problem-solving activities. This is particularly important in mathematics education, where negative attitudes and anxiety often emerge at an early stage.

Multimedia-based learning environments also support self-regulated learning by allowing learners to control the pace and sequence of instruction. Features such as branching navigation, interactive quizzes, and instant feedback enable students to monitor their own understanding and

make adjustments during the learning process. These affordances are consistent with constructivist learning principles, which emphasize learner agency and active knowledge construction.

However, the effectiveness of multimedia learning environments depends largely on the quality of instructional design rather than on technological sophistication alone. Poorly designed multimedia may increase cognitive load and distract learners from core learning objectives. Therefore, the integration of multimedia elements must be guided by clear pedagogical intent and alignment with learning outcomes.

In the context of STEAM-oriented instruction, multimedia learning environments offer additional advantages by facilitating interdisciplinary connections. Digital media can integrate mathematical concepts with visual design, real-world contexts, and creative problem-solving tasks, thereby supporting the holistic learning goals of STEAM education. By embedding these principles within interactive multimedia, instructional designers can create learning environments that are both cognitively supportive and motivationally engaging for elementary students.

This perspective underscores the importance of combining multimedia learning theory, cognitive development considerations, and STEAM pedagogy in the design of elementary mathematics learning environments. The present study adopts this integrated approach by developing a STEAM-oriented interactive learning medium that aligns cognitive principles with interdisciplinary instructional goals.

RESEARCH METHOD

Research Design

This study employed a Research and Development (R&D) approach using the ADDIE instructional design model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009), to systematically guide the development and evaluation of the interactive learning environment.

To provide a clear overview of the research and development process, this study adopted the ADDIE instructional design model, which systematically guided the development of the interactive learning environment. The ADDIE model stages and their corresponding activities and outputs are summarized in Table 1.

Table 1. Research design using the ADDIE instructional development model

ADDIE Phase	Key Activities	Expected Output
Analysis	Curriculum analysis, learner characteristics identification, and problem analysis in elementary mathematics learning	Instructional requirements and design specifications
Design	Development of learning objectives, storyboard preparation, STEAM-oriented learning scenarios, and interface planning	Structured learning design and media blueprint
Development	Creation of interactive multimedia using Articulate Storyline 3, integration of STEAM elements, and internal testing	Prototype of the interactive learning environment
Implementation	Limited classroom try-out and observation of student interaction with the media	Usage feedback and preliminary learning responses
Evaluation	Expert validation, user feedback collection, and product revision	Revised and validated learning product

Rationale for Research Design and Validation Procedures

The selection of a Research and Development (R&D) approach in this study was driven by the primary objective of producing a validated instructional product rather than merely testing an existing instructional intervention. R&D research is particularly appropriate when the intended outcome is a tangible educational product that must undergo systematic design, development, and evaluation processes before implementation in real classroom settings. In the context of educational technology, this approach allows researchers to ensure that the developed learning media is pedagogically sound, technically functional, and aligned with learner needs.

Among various instructional design models, the ADDIE framework was selected due to its systematic yet flexible structure. The five phases of ADDIE—Analysis, Design, Development, Implementation, and Evaluation—provide a clear roadmap for transforming instructional needs into an effective learning product. This model is widely used in instructional design research because it supports iterative refinement and continuous evaluation throughout the development process. For elementary mathematics learning, such systematic design is essential to ensure alignment between learning objectives, instructional activities, and assessment strategies.

The analysis phase played a crucial role in identifying instructional gaps and learner characteristics. By examining curriculum requirements, classroom practices, and students' learning difficulties, the study ensured that the developed media addressed authentic instructional needs rather than hypothetical problems. This needs-based approach strengthens the relevance and contextual validity of the instructional product.

The design and development phases emphasized the alignment of pedagogical principles with technological affordances. Learning objectives were translated into interactive learning scenarios that reflected STEAM principles, while multimedia elements were carefully selected to support conceptual understanding rather than merely enhance visual appeal. This alignment ensured that the use of Articulate Storyline 3 served instructional purposes and supported meaningful learning processes.

Expert validation was incorporated as a critical component of the evaluation process to ensure the quality and feasibility of the developed learning media. Expert review is commonly employed in R&D studies to assess content accuracy, instructional clarity, and media usability before broader implementation. By involving experts in educational technology and subject matter, the study ensured that the learning media met established academic and pedagogical standards. The use of quantitative validation instruments further strengthened the objectivity of the evaluation process.

In addition to expert validation, limited user trials were conducted to examine the practicality and usability of the learning media in real classroom conditions. User feedback provides valuable insights into how learners interact with the media, including navigation clarity, engagement level, and ease of use. This formative evaluation step supports product refinement and enhances the likelihood that the media will function effectively in authentic learning environments.

The use of a pre-test–post-test design in the implementation stage aimed to examine the effectiveness of the developed media in improving students' learning outcomes. Although the study employed a single-group design, this approach remains appropriate for preliminary effectiveness testing in development-oriented research. The combination of expert validation, user trials, and learning outcome analysis provides a comprehensive evaluation framework that addresses feasibility, practicality, and effectiveness in an integrated manner.

Overall, the methodological approach adopted in this study reflects a balance between systematic instructional design and empirical evaluation. By grounding the development process in established instructional design principles and validating the product through multiple evaluation stages, the study ensures that the resulting learning media is both theoretically informed

and practically applicable in elementary mathematics learning contexts.

Participants and Research Context

The research was conducted at SD Putra 1 in East Jakarta during the 2023/2024 academic year. Participants were 20 fourth-grade students selected through purposive sampling to ensure alignment with the study's objectives and to identify learning challenges.

Development Process

During the analysis stage, instructional needs were identified through classroom observation, interviews, and curriculum review. The design stage involved preparing storyboards, flowcharts, instructional materials, and assessment instruments aligned with STEAM principles. During development, the COMATH media was created in Articulate Storyline 3, incorporating interactive animations, quizzes, simulations, and STEAM-based project activities.

The outcome of the development stage was a STEAM-oriented interactive learning environment designed using Articulate Storyline 3. An overview of the main interface of the developed learning media is presented in Figure 1-4.

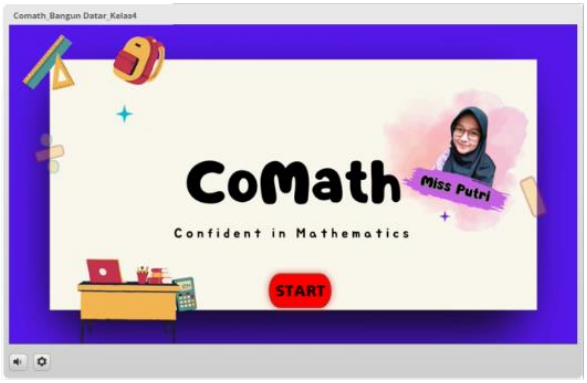

Figure 1. Main interface of Comath.

Figure 2. Interface of login page.

Figure 3. Interface of menu page.

Figure 4. Interface of sub-material page.

Implementation involved classroom trials in which students used the media as part of mathematics instruction. The evaluation included expert validation, student feedback, and effectiveness testing using pre- and post-test measures.

Data Collection and Analysis

Data were collected using expert validation instruments, student response questionnaires, and achievement tests. Quantitative data were analyzed using descriptive statistics, N-gain analysis, and paired-sample t-tests to determine learning effectiveness.

FINDINGS AND DISCUSSION

Results

Following the implementation stage, the quality and effectiveness of the developed learning media were examined through expert validation, user trials, and a pre-test–post-test design involving 20 students. A summary of the evaluation results, including feasibility, learning improvement, and statistical significance, is presented in Table 2.

Table 2. Summary of expert validation, user trial, and learning effectiveness results

Evaluation Component	Indicator	Result	Interpretation
Expert validation	Overall feasibility score	92.75%	Very feasible
User trial	Learning outcome improvement	34.96% increase (pre-test–post-test)	Substantial improvement
Learning effectiveness	N-gain value	0.786 (78.6%)	High effectiveness
Statistical analysis	Paired sample t-test	$t = -24.965$, $p < 0.05$	Significant difference

Expert validation results indicated that the COMATH learning media achieved an overall feasibility score of 92.75%, placing it in the highly feasible category. Students' post-test scores showed a substantial increase compared to pre-test results, with an average improvement of 34.96%. The N-gain value of 78.6% indicated high effectiveness. Statistical analysis confirmed a significant difference between pre-test and post-test scores ($t = -24.965$, $p < 0.05$).

Discussion

Overall, the present study demonstrates that the STEAM-oriented interactive learning environment developed using Articulate Storyline 3 is highly feasible and effective in supporting elementary students' mathematics learning. This conclusion is supported by expert validation results indicating a very high feasibility level (92.75%) and by significant improvements in students' learning outcomes, reflected in the substantial increase between pre-test and post-test scores and a high N-gain value (78.6%). Beyond statistical significance, these findings provide important insights into how interdisciplinary and technology-supported learning environments function pedagogically at the elementary level.

The results of this study align with previous research emphasizing the positive impact of integrative STEM approaches on students' conceptual understanding and problem-solving skills. Becker and Park (2011) reported that interdisciplinary STEM instruction facilitates deeper learning by encouraging learners to connect concepts across disciplines. Although their work focused primarily on STEM, the findings remain highly relevant to the present study, as the STEAM framework extends STEM by incorporating artistic and creative elements that further enhance learner engagement and meaning-making processes. By integrating arts into science, technology, engineering, and mathematics learning, STEAM-oriented instruction offers more flexible, contextualized, and student-centered learning experiences, which are particularly suitable for elementary learners who often rely on visual, concrete, and creative representations to understand

abstract mathematical concepts (Perignat & Katz-Buonincontro, 2019; Wahyuningsih et al., 2020).

These interdisciplinary benefits are further amplified when STEAM instruction is delivered through well-designed interactive multimedia environments. Drawing on the cognitive theory of multimedia learning, effective multimedia design can support meaningful learning by managing cognitive load and promoting the integration of verbal and visual information (Mayer, 2020). In this study, the use of interactive features, animations, and structured learning sequences within Articulate Storyline 3 likely contributed to students' improved comprehension and retention of mathematical concepts. The interactive nature of the learning environment enabled learners to actively engage with the content rather than passively receive information, which is consistent with constructivist perspectives on learning.

In addition to cognitive factors, students' affective and motivational responses appear to play a crucial role in the effectiveness of the developed learning media. Prior research has shown that positive student perceptions of multimedia-supported instruction are strongly associated with increased learning motivation and improved learning outcomes, particularly when interactive or video-based media are utilized (Fikrianto & Susanto, 2023). It suggests that learners' motivational responses may mediate the relationship between instructional design quality and measurable learning gains. The STEAM-oriented interactive media developed in this study likely fostered such positive perceptions by combining interdisciplinary content with engaging visual and interactive elements, thereby encouraging sustained attention and active participation during the learning process.

Beyond motivation and engagement, the effectiveness of the developed learning media can also be interpreted in relation to the development of higher-order thinking skills. STEAM-oriented instruction has been shown to support learners' computational and analytical thinking by encouraging them to engage with problems that require integration of knowledge across disciplines. Talib et al. (2019) demonstrated that STEAM-based learning environments can enhance students' thinking skills by situating mathematical reasoning within technological and design-based problem-solving contexts. This perspective supports the findings of the present study, particularly in relation to students' improved ability to understand and apply geometric concepts.

Furthermore, the role of multimedia design quality should not be underestimated. Munawarah et al. (2021) emphasized that interactive multimedia learning environments that provide immediate feedback, clear navigation, and learner control can significantly enhance students' conceptual understanding. In the present study, these design features were intentionally embedded within the learning media to support students' exploration and reflection processes. As a result, the observed learning gains likely reflect not only improved content delivery, but also enhanced cognitive engagement facilitated by thoughtful multimedia design.

This reinforces the argument that effective STEAM-oriented learning environments require careful integration of pedagogical intent and technological affordances. When these elements are aligned, interactive multimedia can function as a powerful medium for supporting both conceptual understanding and higher-order thinking in elementary mathematics learning.

Taken together, these findings suggest that the effectiveness of the developed learning environment cannot be attributed solely to the integration of STEAM content, but also to the quality of the multimedia design that supports cognitive processing and learner motivation. The results underscore the importance of aligning interdisciplinary instructional approaches with sound multimedia design principles to maximize their educational impact. For elementary mathematics education, this combination appears particularly promising, as it addresses both the conceptual challenges of abstract mathematical content and the developmental characteristics of young learners.

Extended Interpretation of Learning Outcomes and Design Effectiveness

While the quantitative findings of this study demonstrate statistically significant improvements in students' learning outcomes, a deeper interpretation reveals important insights into the mechanisms underlying these gains. The substantial increase in post-test scores and high N-gain value suggest that the developed learning media supported not only short-term performance improvements but also meaningful conceptual understanding.

One key mechanism contributing to this effectiveness is the integration of interactive learning activities that encourage active cognitive engagement. Rather than passively receiving information, students were required to interact with learning content through simulations, quizzes, and problem-solving tasks. This active engagement aligns with constructivist learning theory, which posits that knowledge is constructed through interaction and reflection. For elementary students, such engagement is essential for developing foundational mathematical concepts.

The interdisciplinary nature of the STEAM-oriented learning environment further enhanced students' learning experiences. By connecting mathematical concepts with artistic design, technological tools, and contextual applications, the learning media encouraged students to perceive mathematics as relevant and meaningful. This interdisciplinary framing likely reduced students' resistance to mathematical tasks and supported a more positive learning disposition.

In addition, the visual and interactive elements of the learning media played a critical role in supporting spatial reasoning and conceptual visualization. Geometry concepts such as shapes, angles, and spatial relationships are inherently visual, and traditional text-based instruction often fails to adequately represent these ideas. The use of animations and dynamic representations allowed students to observe transformations and relationships that would be difficult to convey through static images alone.

Motivational factors also contributed to the observed learning gains. As suggested by prior research, students' positive perceptions of multimedia-supported instruction are closely linked to increased learning motivation and persistence. In the present study, the interactive design and learner-controlled navigation likely fostered a sense of autonomy and competence, which are key components of intrinsic motivation. These affective factors may have functioned as mediators between instructional design quality and academic performance.

Importantly, the findings indicate that the effectiveness of the developed learning media cannot be attributed solely to technological features. Instead, it reflects the alignment of pedagogical principles, instructional design strategies, and technological affordances. This alignment ensured that multimedia elements supported learning objectives rather than distracting from them.

Overall, the extended findings reinforce the argument that STEAM-oriented interactive multimedia learning environments offer a promising approach for addressing persistent challenges in elementary mathematics education. By supporting cognitive, motivational, and interdisciplinary learning processes simultaneously, such environments can contribute to more meaningful and sustainable learning outcomes.

Pedagogical and Practical Implications

The findings of this study have several pedagogical implications. For teachers, the results suggest that interactive multimedia learning environments can support conceptual understanding and student engagement in mathematics. The integration of STEAM principles encourages teachers to design learning activities that connect mathematics to real-world contexts and creative problem-solving tasks.

For instructional designers and educational technology developers, this study provides a practical example of how Articulate Storyline 3 can be utilized to develop STEAM-oriented learning

media that are both feasible and effective. Schools and educational policymakers may consider supporting professional development initiatives that enhance teachers' capacity to design and implement technology-enhanced, interdisciplinary learning environments.

In addition, the findings highlight the importance of professional development for elementary school teachers in the area of instructional design and educational technology. While interactive multimedia and STEAM-oriented learning environments offer substantial pedagogical benefits, their effective implementation requires teachers to possess not only technical skills, but also pedagogical understanding of how technology can support learning objectives. Structured training programs that focus on instructional design principles, multimedia learning theory, and interdisciplinary pedagogy may therefore be essential for maximizing the impact of such learning innovations.

The results of this study also suggest that schools should consider adopting a more systematic approach to integrating digital learning resources into the mathematics curriculum. Rather than treating interactive multimedia as supplementary materials, educators and policymakers may view them as integral components of instructional planning. This approach aligns with broader educational goals related to 21st-century skills development, including critical thinking, creativity, and problem-solving. By embedding STEAM-oriented interactive learning environments into regular classroom practice, schools can create more engaging and meaningful learning experiences for elementary students.

CONCLUSIONS

This study addressed the need for more engaging and conceptually meaningful mathematics learning at the elementary level by developing a STEAM-oriented interactive learning environment using Articulate Storyline 3. Through a systematic Research and Development process guided by the ADDIE instructional design model, the study demonstrated that the developed learning media is both highly feasible and effective in supporting students' understanding of plane geometry.

The findings indicate that the integration of STEAM principles within an interactive multimedia environment can enhance elementary students' learning outcomes by supporting cognitive processing, visual representation, and active engagement. The use of interactive features and interdisciplinary learning scenarios enabled students to explore mathematical concepts in a more concrete, contextualized, and learner-centered manner. This suggests that technology-enhanced learning environments, when grounded in sound pedagogical and instructional design principles, can address common challenges in elementary mathematics education, particularly those related to abstract conceptualization and low learner motivation.

From a theoretical perspective, this study contributes to the literature on educational technology and STEAM pedagogy by illustrating how multimedia learning theory, instructional design models, and interdisciplinary approaches can be systematically integrated within elementary mathematics instruction. Practically, the developed learning media provides teachers with a feasible and adaptable instructional resource that aligns with 21st-century learning goals while remaining responsive to the cognitive and developmental characteristics of young learners.

LIMITATIONS & FURTHER RESEARCH

Despite its contributions, this study has several limitations that should be considered when interpreting the findings. First, the sample size was relatively small and limited to a single elementary school, which may restrict the generalizability of the results to broader educational contexts. Second, the study employed a one-group pre-test–post-test design without a control group. Although this design is appropriate for preliminary effectiveness testing within a research and development framework, it does not allow for direct comparison with alternative instructional

approaches. Third, the implementation focused on short-term learning outcomes and did not examine long-term retention or sustained changes in students' attitudes toward mathematics.

These limitations provide important directions for future research. Subsequent studies may involve larger and more diverse samples across different schools and regions to enhance the generalizability of findings. Employing experimental or quasi-experimental designs with control groups would allow for stronger causal inferences regarding the effectiveness of STEAM-oriented interactive multimedia learning environments. Longitudinal research is also recommended to investigate the long-term impact of such learning environments on students' mathematical understanding, motivation, and learning dispositions. Additionally, future studies could explore teachers' instructional practices, design competencies, and professional development needs related to the implementation of STEAM-based interactive learning media, thereby supporting the scalability and sustainability of technology-enhanced STEAM instruction in elementary education.

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