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DEVELOPMENT OF COMIC-BASED MATHEMATICS LEARNING MEDIA WITH A SCIENTIFIC APPROACH FOR TEACHING 3D CURVED SURFACE GEOMETRY IN JUNIOR HIGH SCHOOL

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Abstract

Mathematics was often perceived as a challenging subject for junior high school students, especially on complex topics such as curved surface geometry, partly due to the lack of varied and engaging learning media. Although comic-based learning media had been developed widely, few were specifically designed for 3D curved surface geometry aligned with curriculum standards. This study aimed to develop and validate a comic-based mathematics learning media incorporating a scientific approach for ninth-grade students. The development process followed the ADDIE instructional design model, including analysis, design, development, implementation, and evaluation phases. The media was validated by material and media experts and then trialed with students to assess its feasibility and effectiveness. Results indicated very good ratings from material experts (3.50) and media experts (3.88), along with significant improvement in student responses, increasing from 3.38 in small-scale trials to 3.64 in large-scale trials. Moreover, the media effectively enhanced student motivation, conceptual understanding, and engagement in learning complex mathematical concepts. This research contributed an innovative, scientifically grounded comic-based learning resource consistent with the 2013 curriculum's emphasis on visual learning styles and active scientific inquiry, offering a promising tool to improve mathematics education on curved surface geometry in Indonesian junior high schools.

Keywords: comic-based mathematics learning media, mathematics learning media development, curved surface geometry teaching, scientific approach in education, ADDIE model instructional design, visual learning in mathematics, junior high school mathematics, three-dimensional geometry education, student engagement in mathematics, curriculum 2013 mathematics implementation

Abstrak

Matematika sering dianggap sebagai mata pelajaran yang sulit oleh peserta didik SMP, terutama pada materi bangun ruang sisi lengkung yang kompleks, sebagian disebabkan kurangnya variasi dan daya tarik media pembelajaran. Meskipun media pembelajaran berbasis komik telah banyak dikembangkan, media yang secara khusus dirancang untuk materi sisi lengkung tiga dimensi dan sesuai dengan standar kurikulum masih sedikit. Penelitian ini bertujuan mengembangkan dan menguji kelayakan media pembelajaran matematika berbasis komik dengan pendekatan saintifik untuk siswa kelas IX. Proses pengembangan mengikuti model desain instruksional ADDIE yang meliputi fase analisis, desain, pengembangan, implementasi, dan evaluasi. Media divalidasi oleh ahli materi dan media, kemudian diuji coba pada peserta didik untuk menilai kelayakan dan efektivitasnya. Hasil menunjukkan penilaian sangat baik dari ahli materi (3,50) dan ahli media (3,88), serta peningkatan respons peserta didik dari 3,38 pada uji coba skala kecil menjadi 3,64 pada uji coba skala besar. Media ini efektif meningkatkan motivasi, pemahaman konsep, dan keterlibatan siswa dalam mempelajari konsep matematika yang kompleks. Penelitian ini menghasilkan media pembelajaran berbasis komik yang inovatif dan berbasis ilmiah, selaras dengan penekanan Kurikulum 2013 pada gaya belajar visual dan pendekatan saintifik, sehingga menjadi alat yang menjanjikan untuk meningkatkan pembelajaran matematika materi bangun ruang sisi lengkung di SMP Indonesia.

Kata kunci: media pembelajaran matematika berbasis komik, pengembangan media pembelajaran matematika, pembelajaran bangun ruang sisi lengkung, pendekatan saintifik dalam pendidikan, model desain instruksional addie, pembelajaran visual matematika, matematika tingkat smp, pendidikan geometri tiga dimensi, keterlibatan siswa dalam matematika, implementasi kurikulum 2013 matematika

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INTRODUCTION

Education is a dynamic and comprehensive process shaped by the contributions of notable psychologists and educators who emphasized effective learning practices (Mahmud, 2017). In the Islamic educational tradition, scholars such as Ibn Miskawaih, Al-Ghazali, Al-Muhasibi, and Abu Talib Al-Makki laid foundations focusing on holistic development, nurturing students' emotional and physical aspects (Mahmud, 2017). These values align with Indonesia's National Education System Law No. 20 Year 2003, which frames education as a planned effort to develop students' spiritual strength, self-discipline, personality, intelligence, noble character, and skills essential for personal and national advancement (Undang-undang Republik Indonesia Nomor 20 Tahun 2003).

Teachers play a critical role as facilitators, enabling learning processes characterized by active engagement and guided problem solving (Slameto, 2015). Effective learning requires learners to seek, discover, and critically examine problems under guidance, fostering behavioral changes essential to learning (Mahmud, 2017). This process is influenced by internal factors such as physical and psychological health, and external factors including family, school, and societal environments (Slameto, 2015).

Learning methods and styles within schools significantly impact achievement. Neuro-Linguistic Programming (NLP) classifies learners as visual, auditory, or kinesthetic, promoting alignment of instructional materials to learning styles for enhanced efficacy (Mahmud, 2017). Visual learning has proven effective in conveying complex content and improving retention.

Despite these insights, junior high mathematics education remains challenging due to its abstract nature. Students often find topics difficult, resulting in decreased motivation and engagement (Indaryati & Jailani, 2015). To overcome this, innovative, interactive, and diverse media that concretize abstract mathematical ideas are needed. Comic-based instructional media have emerged as promising tools by blending visual storytelling with pedagogy to enhance engagement and achievement, especially in STEM education (Kwon & Kim, 2012; Moylan & Tipler, 2014; Yang & Wu, 2012).

Nevertheless, research focusing specifically on comic media for teaching 3D curved surface geometry is scarce. This gap signals a critical need for developing targeted media addressing this complex subject (Lestari & Prabowo, 2020).

Several prior studies in Indonesia have explored related themes:

1. Indaryati & Jailani (2015) developed comic-based mathematics media to improve motivation and achievement for grade V elementary students. Their focus was on early mathematics concepts distinct from three-dimensional geometry and a different learner group than this research.
2. Yatno et al. (2015) created a contextually developed comic media for integrated science on sound topics for grade VIII students. Although both studies involved comic media development, differences lie in subject matter and approaches—contextual for science versus scientific approach here.
3. Farida et al. (2018) developed gamified teaching materials on curved surface geometry for vocational students. This study differs by developing comic-based media with a scientific approach tailored for junior high students.

These studies reveal the growing interest and effectiveness of comic-based media for diverse subjects and educational levels in Indonesia. However, none specifically address comic media integrating scientific inquiry steps for 3D curved surface geometry in junior high mathematics, marking this study's unique contribution

At SMP Negeri 2 Mendo Barat, interviews, observations, and exam data from 2019/2020 indicated Grade IX students' average mathematics score of 58.44, reflecting learning difficulties. Observations in 2021 found students preferred visual learning tools such as videos and pictorial presentations, highlighting the opportunity to introduce comic-based media aligned with visual learning preferences (Lestari & Prabowo, 2020).

Globally, comics have been effective in enhancing scientific literacy and motivation (Daryanto, 2013; Sipayung et al., 2020). Their multimodal integration of text, images, and narratives facilitates cognitive processing by reducing load, easing comprehension of complex content, and addressing fatigue and boredom common in mathematics learning (Sweller, 2010).

The ADDIE instructional design model—comprising Analysis, Design, Development, Implementation, and Evaluation—provides a systematic framework to

align learning media with student needs and curricular goals (Tegeh et al., 2014). Indonesia's 2013 curriculum mandates a scientific learning approach emphasizing observing, questioning, experimenting, reasoning, and communicating to foster critical thinking and deep understanding through inquiry (Rohaeti et al., 2019). This methodology was thoughtfully integrated throughout the comic media's design to cultivate critical thinking and promote active engagement in mathematics learning (Fitriani & Leton, 2024; Undang-undang Republik Indonesia Nomor 20 Tahun 2003).

Given the contextual challenges students face in mastering curvilinear geometric forms and the pedagogical advantages of comics, this study addressed a timely and impactful gap by developing and evaluating a comic-based mathematics learning media explicitly tailored for curved surface geometry. The media leveraged students' visual learning strengths, narrative engagement, and scientific inquiry processes to enhance motivation, understanding, and communicative competence among Indonesian junior high school mathematics learners.

The objectives of this study are as follows:

1. To develop comic-based learning media that effectively supports instructional and self-learning activities for curvilinear surface geometry.
2. To integrate the scientific approach mandated by the national curriculum into the media to enhance pedagogical effectiveness.
3. To evaluate the feasibility and effectiveness of the media in improving student engagement, comprehension, and achievement in mathematics.

By addressing these questions, this research aims to contribute innovative instructional solutions and enrich mathematics education, fostering deeper conceptual understanding and sustained learner motivation through comic-based media designed with sound instructional and cognitive principles.

METHODS

This study employed a Research and Development (R&D) design aimed at developing a specific educational product and testing its effectiveness (Sugiyono, 2018). The development of the comic-based mathematics learning media was executed by applying the ADDIE model, a systematic instructional design framework consisting of five phases: Analysis, Design, Development, Implementation, and Evaluation (Tegeh et al., 2014). The ADDIE model provides a structured procedure that promotes iterative development and refinement to ensure media appropriateness and effectiveness in learning.

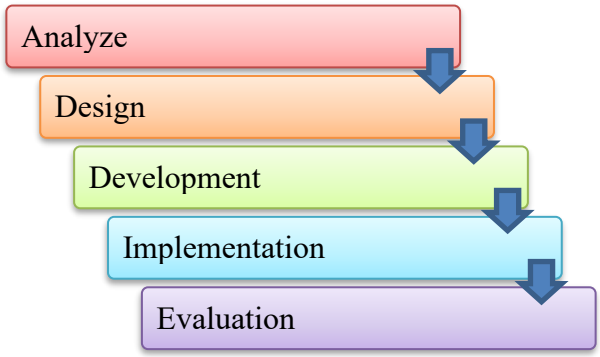

Figure 1. Steps in the ADDIE model

The development process commenced with the Analysis phase, which aimed to determine the precise needs related to learning media at SMP Negeri 2 Mendo Barat. The analysis focused on three core components: needs assessment, curriculum evaluation, and student character review. The needs assessment identified the instructional materials required by students and assessed the availability of supporting learning resources through observations and interviews at the school. Curriculum evaluation examined the 2013 curriculum's demands to align the media with competency standards and learning indicators. Student character analysis aimed to tailor the media according to students' attitudes and learning preferences, particularly considering their challenges in learning mathematics.

In the Design phase, the researcher prepared research instruments including questionnaires for material and media experts and student respondents to evaluate the media's feasibility. Also developed were flowcharts and storyboards outlining the instructional content sequence and student activities embedded within the comic media. These design tools served as blueprints for development.

During the Development phase, a prototype of the comic-based learning media was produced based on the design blueprint. Reference materials were collected and integrated using a scientific approach compliant with curriculum requirements. Validation was conducted by material and media experts, and feedback was used to refine the prototype to readiness for classroom trials.

The media development utilized traditional drawing tools, including pencils, erasers, rulers, drawing pens of various sizes, colored pencils, color markers, and sketchbooks sized A3 and A4, among other materials. The process began with hand-drawn sketches in the sketchbooks, followed by refining the line art and coloring. Completed sketches were then scanned and arranged digitally using Canva. Subsequently, speech bubbles and dialogue were added using the PicsArt application, and the final comic strips were compiled in Microsoft Word.

The developed product consisted of comic-based learning media covering curved surface geometry material. It presented contextual examples through illustrations, texts, and images arranged in comic format. The learning media included core competencies, basic competencies, instructional content, problem-solving exercises, media information, and tips for memorizing and understanding concepts, all woven into a coherent comic narrative. This product was designed for use during mathematics instruction.

The completed media was made available in both print and digital forms to accommodate various learning environments. Selected excerpts of the comic media, illustrating key features such as contextual mathematical concepts, dialogue employing the scientific approach, and visual design elements, are presented below to provide readers with a clearer understanding of the media design.

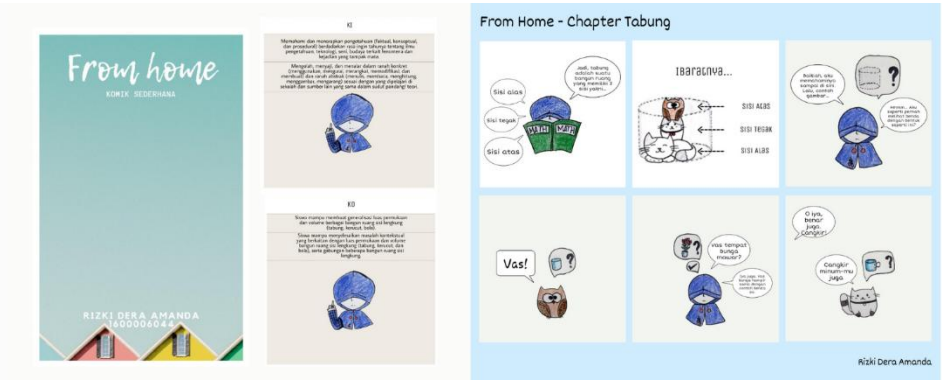

Figure 2. Komik Strips "From Home"

The Implementation phase involved systematic field testing through two levels of trials. A small-scale trial was carried out with 16 purposively chosen students from one class to gather preliminary feedback on usability and content. Based on this feedback, improvements were made before a large-scale trial with 32 randomly selected students from several classes was conducted to evaluate the media's broader effectiveness and acceptance.

Evaluation included both formative assessments during each ADDIE phase for ongoing refinement and a summative evaluation after implementation to measure overall feasibility and learning impact. Data collection instruments comprised validated questionnaires with a 4-point Likert scale assessing content validity, design quality, usability, and the integration of scientific learning principles.

The questionnaires demonstrated high reliability, with a Cronbach's Alpha coefficient of 0.85. Qualitative data were gathered from open-ended questionnaire responses and interviews with teachers and students to provide deeper insights into the media's strengths and areas for enhancement.

Quantitative data analysis involved calculating mean item scores and converting these into qualitative feasibility categories ranging from Very Good to Very Poor (Sugiyono, 2018). Further percentage scores were interpreted according to established criteria for eligibility and revision needs (Mustaming et al., 2015; Tegeh et al., 2014). Thematic analysis was applied to qualitative data for detailed evaluation of participant feedback.

Ethical compliance was ensured through obtaining necessary permissions from school authorities and securing voluntary participant consent, with strict measures to maintain confidentiality and data privacy.

RESULTS AND DISCUSSION

The development of the comic-based mathematics learning media, titled From Home, aimed at Grade IX students and specifically covering the curvilinear surface geometry material, was systematically executed following the ADDIE instructional design model. This model consists of five iterative and interconnected phases: Analysis, Design, Development, Implementation, and Evaluation (Tegeh et al., 2014). The resultant media was made accessible in both print and online digital formats, providing versatile options

geared towards accommodating the varied learning environments and preferences of students.

1. Development and Trial Process

The initial Analysis phase involved comprehensive observations and interviews conducted at SMP Negeri 2 Mendo Barat, authorized by the Faculty of Teacher Training and Educational Sciences, Universitas Ahmad Dahlan. This phase identified key learning challenges—including students' low enthusiasm and motivation towards mathematics, their perception of mathematics as a difficult subject, and the scarcity of diverse instructional models and visually engaging learning resources. The teaching and learning environment at the school was found to be generally monotonous, lacking innovative media that could stimulate active student participation. These findings underscored the urgent need for engaging, varied instructional media that align with students' visual learning styles, a need further reinforced by the Indonesian 2013 curriculum's emphasis on scientific learning approaches.

The Design phase consisted of formulating detailed storyboards and flowcharts that mapped the narrative structure, thematic content, and interactive features of the comic media. This meticulous planning ensured that the media content scaffolded students' understanding systematically while embedding the scientific inquiry steps crucial to curriculum standards. In parallel, the research instruments—namely validation questionnaires for material experts, media experts, and student respondents—were designed and validated to ensure precise and reliable data collection during evaluations.

During the Development phase, the raw designs were transformed into a polished comic media prototype. The fabrication process involved crafting sketches using pencils and traditional art tools, progressing through line art reinforcement and vibrant coloring via crayons and markers, to digital editing with software including Canva and PicsArt. This enabled the integration of text, dialogue bubbles, and coherent visual storytelling aligning with the pedagogical objectives. Input from supervising lecturers informed quality control before formal media validation.

Validation constituted a critical stage where two expert groups—material experts, comprising mathematics educators and teachers, and media experts specializing in educational media design—reviewed the comic for content validity, linguistic clarity, visual aesthetics, and alignment with scientific approach requirements. Suggestions included the addition of detailed answer keys, more exercise variety, enhancement of geometric nets visuals, improved cover design, and enriched backgrounds to elevate realism and engagement.

Implementation followed a dual-phase trial design. A small-scale test engaged 16 purposively selected students representing the target population, serving as a pilot to capture initial reactions and pinpoint usability issues. Feedback from this phase facilitated targeted refinements. Subsequently, a large-scale trial with 32 students randomly sampled across classes assessed broader applicability and effectiveness under more natural instructional circumstances, further informing the final adjustments.

The noticeable difference between student ratings in the small-scale trial (mean score of 3.38, “Good”) and the large-scale trial (mean score of 3.64, “Very Good”) can be explained by students’ initial unfamiliarity with the comic format and new instructional method offered by the media. Research indicates that exposure to novel learning media typically requires an acclimation period before learners can fully leverage its advantages (Kaufmann et al., 2000). Moreover, initial limited guidance in the small trial may have hindered optimal interactions with the media. The higher rating during the large-scale trial reflects successful iterative revisions and growing student comfort, affirming the importance of formative evaluation within the ADDIE framework (Tegeh et al., 2014).

The central role of visual media in this study aligns with empirical evidence that visual and multimedia learning tools concretize abstract mathematical concepts, sustain motivation, and improve comprehension (Muhaimin & Juandi, 2023)(Az-Zahroh et al., 2019). Comics, which uniquely combine illustrative narratives with verbal explanations, stimulate both visual and auditory cognitive pathways simultaneously, effectively managing intrinsic cognitive load and aiding meta-cognitive learning strategies (Sweller, 2010).

To provide a comprehensive understanding of the media's feasibility and effectiveness, the following section presents a detailed quantitative analysis of evaluation results from material experts, media experts, and student respondents during both the small-scale and large-scale trials. These data offer important insights into the media's strengths and areas for improvement, serving as a foundation for the subsequent interpretation and discussion of the media's educational impact.

2. Evaluation and Analysis

Quantitative data gathered through Likert-scale questionnaires revealed robust acceptance and satisfaction across all evaluators. Material experts rated content quality, conceptual accuracy, and curricular alignment with an average of 3.50 ("Very Good"). Media experts assigned an even higher average score of 3.88 ("Very Good"), praising the comic for its visually appealing design, ease of use, and innovative instructional elements. Students showed positive progression in acceptance and appreciation between trials, underscoring the media's usability and pedagogical value.

The following table summarizes the overall assessment scores across various aspects, providing a clear comparative view of the evaluation results:

Table 1. Overall Calculation Results of Expert Material, Expert Media, and Student Response Questionnaires

No.	Aspect	Score	Quantitative Data Criteria
1	Material Expert	3.50	Very Good
2	Media Expert	3.88	Very Good
3	Student Response (Small Class)	3.38	Good
4	Student Response (Large Class)	3.64	Very Good
5	Scientific Aspect	3.59	Very Good
Total		**17.98**	**Very Good**
Average		**3.60**	

These aggregated scores illustrate that the From Home comic-based learning media achieved consistent "Very Good" ratings across most dimensions, with the overall

average score of 3.60 reflecting its high feasibility and effectiveness as an instructional tool.

The scientific aspect of the media, assessing its embedding of the learning cycle steps—observing, questioning, experimenting, reasoning, and communicating—received a consistent rating of 3.59 ("Very Good") from both experts and students. This confirms that From Home effectively supports the active, inquiry-based learning model described in the 2013 national curriculum (Deputy Minister of Education and Culture, 2014; Rohaeti et al., 2019).

3. In-Depth Discussion

The findings of this research strongly resonate with Mayer's Multimedia Learning Theory, which posits that carefully integrated verbal and visual information reduces cognitive overload and thereby facilitates meaningful learning (Mayer, 2002; Sung & Mayer, 2012). The engaging, clear, and interactive design of From Home embodies Clark & Mayer (2016) principles advocating for learner-centered instructional design with high usability and motivation enhancement.

The observed increase in student acceptance between small and large-scale trials illustrates the efficacy of iterative media refinement and formative evaluation embedded within the ADDIE model. This demonstrates the indispensable role of ongoing feedback and iterative design in tailoring educational media to learner needs and instructional efficacy (Tegeh et al., 2014).

Yang & Wu (2012) supports the use of narrative-driven digital comics as effective motivational tools for enhancing critical thinking in STEM subjects, which gel well with the positive engagement observed in this study. In addition, Sweller's Cognitive Load Theory explains how delivering content simultaneously through dual channels—visual and verbal—minimizes extraneous cognitive load, allowing students to allocate cognitive resources toward understanding complex mathematical reasoning rather than decoding instructions (Sweller, 2010).

The comic's explicit integration of the scientific approach, featuring steps from observation to communication, aligns with Indonesia's 2013 curriculum's inquiry-based learning focus, developing students' higher-order thinking and active participation in

mathematics learning (Rohaeti et al., 2019; Undang-Undang Republik Indonesia Nomor 20 Tahun 2003).

Qualitative feedback from teachers and students validates the media's effectiveness in reducing math anxiety and promoting an enjoyable learning atmosphere, consistent with research findings that comic-based learning media increase motivation and engagement in science education (Sipayung et al., 2020).

In summary, the From Home comic's thoughtfully layered composition—including an engaging cover design, relatable character introductions, rich contextual explanations, systematically integrated scientific inquiry steps, and well-developed exercises with comprehensive answer keys—provides a holistic educational experience. It not only aligns with curricular standards but also addresses essential cognitive and affective learner needs, fostering sustained motivation and deeper mathematical understanding.

CONCLUSION

This study successfully developed a simple comic-based mathematics learning media focused on curved surface geometry through the ADDIE instructional design model. The development stages included a comprehensive needs analysis, material and curriculum review, initial design of instructional materials and research instruments such as flowcharts and storyboards, followed by prototype development, implementation in classroom trials, and an extensive evaluation of its feasibility and effectiveness.

Evaluations gathered from material experts, media experts, and student participants in both small-scale and large-scale trials consistently indicated that the media met high standards of quality and efficacy. The media achieved very good average scores across all assessment dimensions including material validity (3.50), media quality (3.88), student responses in small classes (3.38) and large classes (3.64), and scientific approach fidelity (3.59). These results collectively confirm that the comic-based learning media is a highly suitable and effective resource to support Grade IX students' mastery of curved surface geometry.

The findings endorse the use of this media both inside formal classroom settings and as an independent learning tool outside the classroom, aiming to enhance student

motivation, understanding, and engagement in mathematics learning. Further, the study recommends continued research to explore the long-term impacts and wider applicability of comic-based media in mathematics education. This media development may also serve as a foundation for future instructional innovations, inspiring the creation of similar educational resources with improved quality and broader reach.

While the study produced promising results, it was conducted during the extraordinary circumstances of the COVID-19 pandemic, which inherently introduced certain limitations. The necessity to conduct data collection and media implementation mainly via online platforms such as WhatsApp, Zoom, and Google Meet limited face-to-face interaction and hands-on testing environments. The research setting was also relocated owing to pandemic restrictions, which may have influenced contextual factors impacting the study. Additionally, the comic learning media is currently available only in digital soft file format and lacks formal ISBN registration, which could affect its distribution and recognition.

Despite these challenges, the research offers valuable insights and a practical solution for improving mathematics education through comic-based media. Future efforts should aim to address these limitations by enabling in-person trials, expanding dissemination methods, and securing formal publication credentials for the media.

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