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Development of a Group Investigation-Based Mathematical Electronic Comic to Improve Junior High School Students' Mathematical Representation Skills

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ABSTRACT

Mathematical representation skills are an essential competency for students to succeed in the National Assessment. However, the consistently low representation of skills among junior high school students necessitates learning innovations that integrate both cognitive and affective aspects, particularly in mathematical resilience. This study aims to develop a Mathematics E-Comic based on the Group Investigation model and evaluate its validity, practicality, and effectiveness in improving students' mathematical representation skills. Adopting the Research and Development (R&D) method with the ADDIE model, the product was developed using Canva and Flipbook platforms as interactive media to support independent and collaborative exploration. The research subjects involved 64 seventh-grade students at SMP NU Darul Ma'arif Indramayu during the 2025/2026 academic year, divided into experimental and control classes. The results indicated that the developed Mathematics E-Comic is highly feasible, proven empirically through media expert validation with an average score of 94.93% and material expert assessment with 91.64%, both falling into the "very valid" category. Furthermore, the media demonstrated high practicality, evidenced by a 92% teacher response score and an 85% student response rate. Data analysis revealed a significant difference in mathematical representation skills between students using Group Investigation-based E-Comics and those in conventional learning. These findings confirm that this media serves as an innovative alternative that enhances representation skills while sustainably strengthening students' mathematical resilience. The integration of visual narratives and group work creates a contextual, interactive experience that fosters active engagement in mathematical discussions.

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1. INTRODUCTION

Mathematics is a discipline that plays a fundamental role in human life, serving as an instrument for developing logical, analytical, and systematic thinking. In modern education, mathematics learning no longer merely emphasizes mastering technical procedures, but rather the formation of conceptual understanding that can be transferred to everyday practical situations [1], [2], [4]. The core of this conceptual understanding lies in the ability to represent mathematically. As a crucial process standard, representation helps students organize ideas, communicate reasoning, and bridge abstract concepts into manipulable forms such as diagrams, tables, and symbols [1], [2]. The quality of a student's understanding can even be traced through the "representational trail" they produce during the problem-solving process [3], [10].

However, major challenges arise in learning geometry, especially in quadrilaterals. This material is highly strategic because it demands the simultaneous integration of visual, symbolic, and verbal representations. In fact, many students experience difficulties in drawing shapes accurately, connecting geometric properties with formulas, and even difficulty translating contextual problems into mathematical models [15], [33]. Failure to coordinate these various representational registers often becomes the source of fatal procedural errors [2], [3]. In addition to cognitive obstacles, affective aspects such as low mathematical resilience also exacerbate this condition. Students tend to give up easily and lack resilience when facing complex mathematical challenges [16], [18].

This condition emphasizes the need for innovative learning media that can provide strong visual-spatial support while facilitating collaborative work. Along with technological developments, digital media such as mathematical e-comics have emerged as a promising solution. E-comics can combine narrative and visual representation of problems in stages, effectively reducing students' cognitive burden in understanding the problem context before moving on to formal forms [20], [23]. To ensure that e-comics are not merely passive consumption media, integration with the Group Investigation model is very relevant. This model emphasizes planning, investigation, and discussion, which allows for mathematical argumentation and strengthening resilience through socio-academic support within the group [8], [14].

Although the potential of digital media and collaborative models has been widely discussed, there is a clear gap between theory and practice in the field. Based on observations at SMP NU Darul Ma'arif (64 participants), students showed a strong reliance on teacher explanations and tended to be passive and give up easily when faced with non-routine questions. Students also rarely engage in productive discussions related to the subject matter when in groups. Therefore, this study aims to fill this gap by developing a Group Investigation-Based Mathematics E-Comic on quadrilaterals. This study is expected to provide an alternative, innovative learning medium to improve mathematical representation skills while strengthening students' mathematical resilience at the junior high school level.

2. METHOD

a. Research Design

This research uses the Research and Development method, which aims to find, develop, and verify learning products [6], [12]. The development model applied is the ADDIE model, which consists of five systematic stages: Analysis, Design, Development, Implementation, and Evaluation [13], [28].

b. Research Subjects

The research subjects were selected by purposive sampling at SMP NU Darul Ma'arif Indramayu in the 2025/2026 academic year. Participants consisted of 64 seventh-grade students, divided into two groups: class VII H (32 students) as the experimental class and class VII G (32 students) as the control class.

c. Products Developed

The product of this research is a learning medium in the form of a Mathematics E-Comic based on the Group Investigation model. This medium was developed using the Canva and Flipbook platforms for the quadrilateral geometry topic. It is designed as an interactive teaching material that combines visual narrative with group investigation stages.

d. Research Instruments

Researchers used data-collection instruments consisting of validation sheets to measure product feasibility by material, media, and language experts. A questionnaire was used to assess the practicality of the media based on teacher and student responses. The Representation Ability Test was used as an evaluation instrument to assess the product's effect on students' cognitive achievement.

e. Validation Procedure

The validation process involved three subject matter experts (material experts): 5 junior high school mathematics teachers, 2 Mathematics Education Lecturers, and 2 lecturers who are experts in learning media. Validation by material experts focused on the authenticity of the concept and the quality of the learning content, while media validation focused on the visual design, readability, and functionality of the digital media. The researchers compiled three instrument grid tables as assessment guidelines for the verifiers.

f. Implementation Procedure

The implementation stage involved comparing two treatments: Experimental Class: Using Group Investigation-based Mathematics E-Comics. Students were directed to explore concepts collaboratively through narrative guidance in the comics. Control Class: Using conventional learning dominated by lecture methods and giving independent practice questions [12], [29].

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g. Data analysis

The data obtained were analyzed quantitatively and qualitatively. Feasibility and Practicality Test: Calculated using a percentage formula to determine the level of media validity from experts and the level of practicality from users [11]. Effectiveness Test: Conducted by comparing the results of the mathematical representation ability test between the experimental class and the control class using statistical tests (such as the Independent Sample T-Test) to see the significance of differences in learning outcomes.

In this study, the subjects of the comic media feasibility test validation included two validators: a material expert and a media expert. In this study, the researchers created three instrument grid tables for the material expert and media expert assessments. The material expert verifier was used to obtain data on the form of product quality, including the originality of the concept and the learning content, as shown in Table 1.

Table 1. Material Expert Instrument Grid

Aspect	Indicator	Item
Content Eligibility	Suitability of material with learning outcomes	1
	Accuracy of concept definition	2
	Properties of quadrilaterals	3
	The truth of the area and circumference formulas	4
	Suitability of material and example questions	5
	Complexity of Plane Material	6
Presentation Eligibility	Sequence of material presentation flow	7
	The clarity of the image supports the concept	8
	Availability of comprehension practice questions	9
	Presentation of problems relevant to life	10
Language Eligibility	Accuracy of mathematical terminology	11
	Clarity of instructions and language of materials	12
	Language according to the students' cognitive level	13
	Spelling and punctuation conventions	14

Media expert tools were used to collect data in the form of cover design quality, content layout, typography, and illustrations, as shown in Table 2.

Table 2. Media Expert Instrument Grid

Assessment Aspects	Assessment Indicators	Item
Ease of Use	Clarity of instructions for using e-comics	1
	Ease of media access	3
Benefits	E-comics are easy to visualize concepts	6
Visual Design	Accuracy of font type selection	4
	Proportionality of text and image layout	5
Clarity of material	According to the learning objectives	2

The validation results from material experts provide an overview of the feasibility of mathematical e-comics. from the aspect of the suitability of the material content, the accuracy of the mathematical concept, as well as the integration of material with learning objectives.

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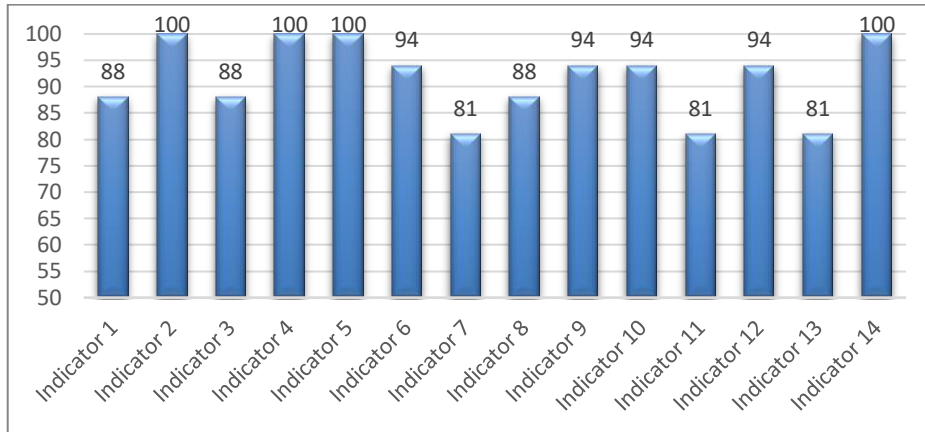


Figure 1. Level of Validity of Subject Matter Experts

The validation results from material experts on 14 indicators showed a very high level of feasibility, with scores ranging from 81% to 100%. In general, this data confirms that the mathematical content in the E-Comic is scientifically accurate and in accordance with learning objectives. Cumulatively, the average validation score from material experts shows the "Very Valid" category. This finding proves that the Group Investigation-based Mathematics E-Comic is not only visually appealing (as validated by media experts), but also has strong academic integrity. The material presented is ready to be used to trigger students' mathematical representation abilities without any misconceptions.

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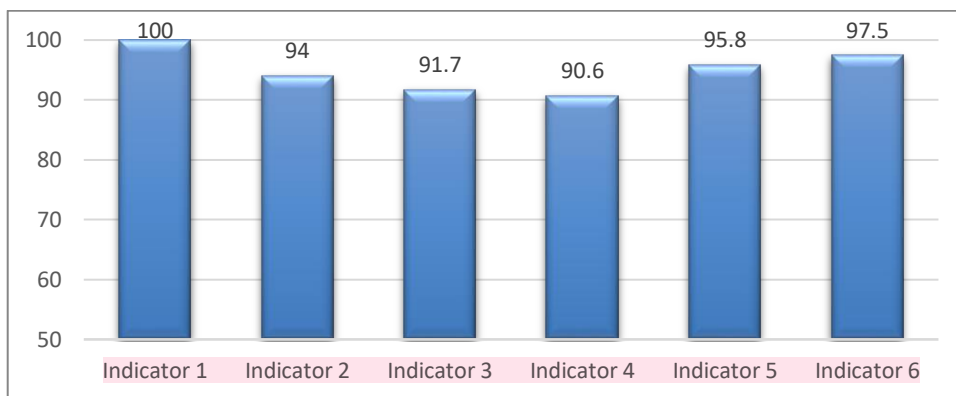


Figure 2. Media Expert Validity Level

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Based on the validation test conducted by media experts on the development of the Mathematics E-Comic, quantitative data were obtained on six main indicators. Overall, this medium achieved a very high average score, ranging from 90.6% to 100%. The average percentage across all indicators indicates that this Group Investigation-based Mathematics E-Comic falls in the Very Valid or Very Feasible category. This result confirms that the product has met the theoretical feasibility criteria for use as a learning tool in an effort to improve students' mathematical representation skills at SMP NU Darul Ma'arif.

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3. RESULTS AND DISCUSSION

This section explains the research results and provides a comprehensive discussion. The discussion can be divided into several subsections.

3.1. Comic Media Implementation Stages

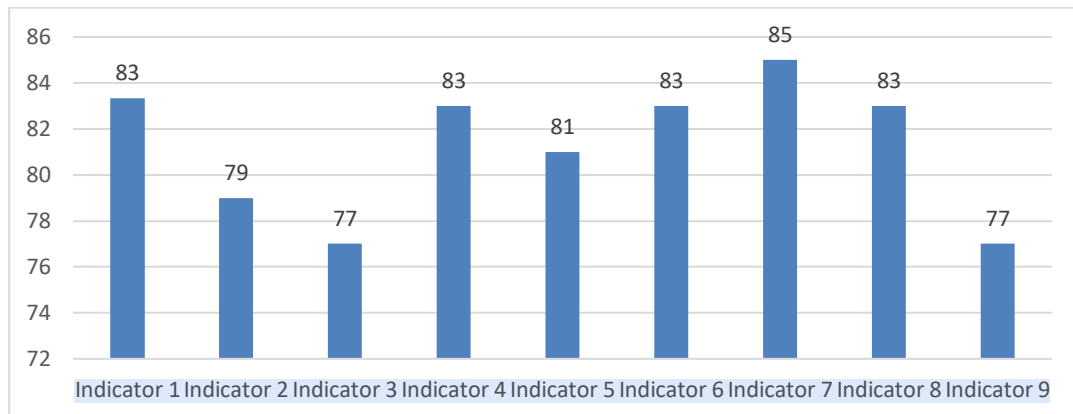


Figure 3. Level of Practicality

The implementation phase is crucial for obtaining empirical information regarding the effectiveness and user response to the developed comic media. This product trial involved 64 seventh-grade students at NU Darul Ma'arif Middle School and focused on quadrilaterals. The implementation results showed that the majority of students responded positively, indicating that the e-comic media created an engaging and interactive learning experience.

In line with the response results, the media's practicality was measured using nine main indicators following an expert validation stage. The data shows that the practicality score ranges from 77% to 85%. This achievement confirms that the Group Investigation-based Mathematics E-comic is in the Practical to Very Practical category. This high level of practicality demonstrates that the developed media is not only theoretically valid but also easy to use and efficient in supporting group investigation activities in the classroom. This condition is in line with the findings of previous research, which stated that visual narratives can increase students' cognitive and affective engagement in mathematics learning [10]. Comic media is also considered able to help students more easily understand the concept of constructing a square plane. Presenting material accompanied by concrete images minimizes misunderstandings and reduces student boredom during the learning process. This supports the opinion that visual media plays an important role in facilitating the understanding of abstract concepts [11].

3.1.1 Operational Excellence (Indicator 7: 85%)

The highest score was achieved for Indicator 7, at 85%. This indicates that the media has excellent readability and clarity of instructions. In the context of e-comics, this achievement demonstrates that the combination of visual elements and narrative text can guide students independently without requiring excessive teacher intervention.

3.1.2. Efficiency of Use (Indicators 1, 4, 6, 8: 83%)

The consistent 83% score indicates that this medium is highly practical in terms of time management and ease of access. The use of digital platforms enables students at SMP

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NU Darul Ma'arif to access materials flexibly, supporting the Group Investigation model, in which each team member needs quick access to information sources for discussion.

3.1.3 Evaluation of the Lowest Indicator (Indicators 3 & 9: 77%)

Indicators 3 and 9 recorded the lowest scores (77%). Although still in the practical category, this provides an academic signal that several technical aspects are involved, such as connection stability when opening Flipbook links or the storage load on students' devices, which may require attention. However, this value does not reduce the operational feasibility of the media in learning as a whole.

3.2. Comic Media Evaluation Stage

The evaluation stage is the final stage in the ADDIE model, which assesses the feasibility and effectiveness of comic media. The evaluation was conducted after the implementation stage through validation by media and material experts, as well as questionnaires on the practicality for teachers and students. The evaluation results showed that comic media was included in the category of feasible and effective for use in learning. Comic media was considered appropriate for junior high school students, both in terms of language, visual presentation, and content. The use of clear fonts, concise text, and communicative language made it easier for students to read and understand dialogues containing the concept of constructing a square plane. Visualization in comics significantly enhanced learning effectiveness. Colorful illustrations with appropriate contrast can increase students' attention and motivation in learning mathematics material [12]. Other research also shows that the use of visual-based media can improve students' conceptual understanding and higher-order thinking skills [13].

3.3. The Relevance of Comic Media in Mathematics Learning

Comics were chosen as a learning medium because they can convey information concisely yet meaningfully. The combination of images and short texts allows students to retain information longer in long-term memory [14]. In addition, comics provide more concrete learning situations, helping students connect mathematical concepts to real-life contexts [15].

The findings of this study are in line with previous research, which stated that comic media can significantly increase students' interest in learning, independence, and learning outcomes [16], [17]. Thus, comic media can be used as an effective alternative learning medium in mathematics learning in junior high schools.

3.4. Discussion

The first stage is the analysis stage, which is the first step for the researcher. At this stage, the researcher analyzed the problems that occurred during the learning process based on the product developed at SMP NU Darul Ma'arif. The problems obtained were based on observations that students still did not understand the problem in the problem, were not thorough, and did not understand the concept of constructing a square area. Therefore, the researcher conducted a product analysis of these problems to meet the needs and

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characteristics of students who use comic media. This design stage is when the form or design of the comic media is determined. Here, the researcher began developing the comic media design, starting with writing dialogue, creating characters, drawing, coloring, and printing the comic. This design stage is the initial stage for the researcher to design the comic he wants to create, so investment is needed in the next product development stage.

The following is an example of the comic design stages for the cover section.



Figure 4. Comic Cover Design Stages

This development stage is where researchers turn the product into a tangible form based on the results of the previous design stage, which they can then use to implement it into learning techniques. The product to be produced is a comic media development product, produced using print media, and used to develop other products. Therefore, the final form of the product developed in this study is print media. To meet the product updates that will be produced in this study, the creation of comics was developed based on packaging books in schools and students as a reference for researchers in designing components to be developed, as well as a source of reference materials used in comic development. To develop comics for print media, researchers used the Canva application to design previously created comic components, including the front cover.

Introduction, character introduction, table of contents, learning objectives, learning materials, author biography, and back cover. After the design of the comic media development product components is completed and the comic media is developed, the next stage is validation. Based on the results, the comic learning media is deemed valid and feasible to implement. This is due to several aspects, namely, this comic learning media received a total percentage of 94.93% from media experts and 91.64% of material experts, thus meeting the eligibility criteria. The material's eligibility can be seen in its quality and the usefulness of the comic.

Product trial stage (Implementation), where researchers complete the product trial to determine whether the development of comic media can maximize the knowledge of seventh-grade students at SMP NU Darul Ma'arif. To see the benefits of innovative products, it is essential to test them to maximize student learning about rectangular building materials. This media research study was conducted with 64 students. Some students find learning to build a rectangular area using comic media very interesting because the storyline in the comic's storyline covers life, and its images in the comic are very engaging. The advantages

of this comic media make it easier for students to understand rectangular building materials and help prevent students from becoming bored during learning activities.

The final stage is the evaluation stage. In the ADDIE development model, the evaluation stage is the final stage. This stage examines whether comics can be used effectively to maximize student learning outcomes. Students are evaluated after the product implementation stage. The evaluation stage aims to determine whether the product tested on students is feasible. Based on the validity tests conducted by media and material experts, as well as practicality tests conducted by teachers and students, researchers can improve the comics based on the suggestions provided.

The research results show that the resulting comic media is feasible and effective. This is due to the media's suitability for the students' characteristics. For example, the material in the comic provides clarity consistent with the images. The bold text and language presentation are tailored to students' characteristics, making it easier for them to read and understand the dialogue about building a rectangular house.

Images have a big influence in comic media. Illustrations in various attractive colors, based on the image's contrast, certainly pique students' interest in learning fraction material and make them happy [26]. Another study stated that comic media can improve conceptual understanding.

High-level thinking skills are a visual role [16]. Research states that the development of comic media in learning to build square houses in junior high schools [14]. Comic media was chosen as a learning medium, as it cannot be separated from its own characteristics: pictures and short texts that convey a lot of meaning. In comic-based learning media, it is necessary to include lessons in comic books so that they remain permanently in students' memories and are easy for them to understand [32]. Not only that, when faced with concrete situations that yield inherent results, students can remember the material more strongly, as comics can spark students' enthusiasm for learning [17]. In the learning process, comic media as the starting point will make it easier for students, especially in grasping the perception of abstract lessons, which must be presented concretely.

In this situation, comics play an important role in expressing abstract perceptions into concrete examples of everyday life [20]. In developing innovations in comic media like this, previous research has sought to develop comic media in facilitate learning outcomes [27], [35], [36]. The existence of comic media is very important for students in the learning process because the visual media developed will make them more motivated in the learning process. The use of mathematical comics is also effective in developing character, especially in discipline and hard work. Before treatment, these two aspects were already in the good category, and after treatment, they were increased to the very good category.

Several previous studies support the results of this study. Comic media is a teaching material based on the results of problem analysis conducted by researchers in their fields, aiming to arouse students' interest in learning and make learning more enjoyable without guidance [26]. In the development of comics, which foster an understanding of emotional independence, they serve as an interesting medium for providing information in an attractive form. The development of comic media can also increase student independence [21]. Comic media given to students can improve their abilities, making it suitable for use in learning.

This can be shown in validation results from media, material, and learning experts, which demonstrate that comic media can improve abilities [5].

Learning assisted by comic media on learning outcomes produces effectiveness in its delivery, so that student learning outcomes are classified as good [34]. Based on other studies, student learning outcomes after learning indicate that comic-based learning is more effective than non-comic learning. This is because comic learning media can trigger student interest in the learning process, stimulate student interest in reading, and follow the flow [33] [37].

4. CONCLUSION

Based on the results of the research and discussion, it can be concluded that mathematical comics featuring geometric shapes, such as flat rectangular shapes, are "Very suitable" for use in mathematics learning. This is evidenced by the assessment of media experts who gave an overall score of 94.93%. and material experts with a score of 91.64%. All are in the "very feasible" category for testing. The alignment of the results is also evident in the teacher and student response tests, where the average percentage of teacher responses in the aspects of material presentation, product effectiveness, and media display was 92%, with a "very feasible" rating. The student response test in small groups with 5 students scored 85%, and in the large-group experiment, it scored 97%, both in high criteria. The recommendation based on the results of this study is that the mathematical comic about rectangular flat building materials can be widely implemented in learning in grade VII junior high school. In addition, it is recommended to further develop the language to achieve greater perfection. Training for teachers in the use of digital comic media is also important to ensure the effectiveness of material delivery. Thus, this learning approach can not only improve students' understanding of rectangular flat building materials but also make the teaching and learning process more interesting and interactive.

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